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ROYAL AERONAUTICAL SOCIETY

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Edited for the Council by J. LAURENCE PRITCHARD, Fellow

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NOTICES

Chairman Elect

At a meeting of the Council held on June 17th, Lieutenant-Colonel H. T. Tizard, A.F.C., Fellow, was elected Chairman for the year 1924-1925. Colonel Tizard will assume office on October 1st.

Scottish Executive Committee

Mr. William Stancliffe Shackleton has been elected a member of the Scottish Branch, and has joined the Executive Committee of that Branch.

Election of Members

The following members were elected at a meeting of the Council held on June 17th:—

Members—Mr. C. L. M. Brown and Mr. D. E. Williams.

Foreign Member—Mr. A. P. Loening.

Students—Mr. W. A. Crabbs and Mr. R. L. Mills.

Examination

Provided that sufficient entries are received, the Society's examination for Associate Fellowship will be held on Monday, September 22nd (Part I.), and Tuesday, September 23rd (Part II.). Entry forms may be obtained from the Secretary and must be returned duly completed not later than Monday, August 25th.

Annual Holidays

The Offices of the Society will be closed from August 1st to 11th.

Erratum

The attention of the Editor has been called to the review of "Mechanical Properties of Fluids," published by Messrs. Blackie and Sons, Ltd., in the April issue of the JOURNAL. The symbol " w " should be " ω," and the criticism which follows that the symbol is overworked is one directed against mathematical notation generally and not against its accepted use in this book.

W. LOCKWOOD MARSH, *Secretary.*

PROCEEDINGS

EIGHTH MEETING, 59TH SESSION

A meeting of the Royal Aeronautical Society was held at the Royal Society of Arts, John Street, Adelphi, London, on Thursday, February 7th, 1924. Colonel A. Ogilvie (the Chairman of the Society) presided.

The CHAIRMAN, in introducing Squadron Leader R. B. Maycock, O.B.E., and calling upon him to read a paper on "Airmanship at Sea," said that he was very well qualified to speak on this subject, as he believed they would all agree when they had heard the paper. His (the Chairman's) first recollection of Squadron Leader Maycock was when he came to Eastchurch, about 1915, and tried to instil some sort of discipline into the Royal Naval Air Service. He did not know that he had had very much success with him (the Chairman), but with the rest of the station he was certainly most successful. Coming to the subject of the paper, the Chairman said that some of those present would know, and the remainder would be interested to know, that Squadron Leader Maycock was in charge of the Development Flight which went round the South Coast and on to the Scillies to test the ability of large flying boats to stand proper sea conditions; the experience obtained on that flight was of the greatest value, and had been the source of much progress in the handling of seaplanes at sea.

Squadron Leader MAYCOCK then read his paper:—

AIRMANSHIP AT SEA

MR. CHAIRMAN, LADIES AND GENTLEMEN,

I may as well confess at once to the fact that when I was asked to lecture some time ago the term "Airmanship at Sea" was selected as the title whilst my subject was still at the back of my mind. On settling down to my task, however, I found that the field was too wide for me to attempt to cover it conveniently in one paper. I propose, therefore, with your kind permission, to confine my remarks to that part of airmanship which concerns the handling and maintenance of seaplanes on the water, or as has been suggested to me the "harbour" side, rather than the "deep sea" side, which covers rising from the sea and landing, flying over the sea, and the many important air duties the pilot must be master of before proceeding on patrol, reconnaissance or a bombing expedition. I trust that I shall be forgiven if it is found necessary to deviate into side issues occasionally for the purposes of illustration and comprehensive understanding.

Treating the harbour side of airmanship as a whole, my views may be considered somewhat pessimistic, whereas in reality I am genuinely optimistic, as I feel that whatever our present difficulties may be they can all be dispersed by further practical study side by side with theoretical study of the problems we are faced with.

In most cases theory is correct, but occasionally it will not work out in practice except under *the* ideal conditions surrounding the theorist.

Again, in my broad treatment, pilots far more qualified than myself to expound the subject may be drawn into the vortex of sweeping statements concerning practical experience.

From them I must crave indulgence and ask that they should not take too literally to heart statements which in their case are not applicable.

The views are entirely my own and must not be taken *ipso facto* as those of the Air Ministry, whose kind permission I have obtained to express them.

I have some slides to show you, many of which have been kindly lent me by Wing Commander Cave-Browne-Cave, who gave an excellent lecture some time ago before the Royal Aeronautical Society on the practical aspects of seaplanes.

In introducing this subject it is with the purpose of pleading for a more practical conception of the difficulties experienced by those destined to go down to the sea in seaplanes, in the hope that it will be more fully realised that not until this amphibious knowledge is generally acquired by those responsible for handling seaplanes can seaplane design and construction advance as rapidly as it otherwise might.

That seaplanes have not advanced at anything like the rate of progress of the aeroplane is well known.

There are several outstanding reasons for this, the most familiar being due to the very much heavier demands for land planes during the Great War.

The tremendous start which this side of aviation obtained in the great race for aeronautical progress has kept all eyes on the winner, and the fortunate "backers" have spared no effort to keep their lead; leaving the seaplane competitor so far behind that it is still striving to overcome its teething troubles. As I said before, there are other big factors retarding progress.

Seaplanes did not get a clean start from the embyro stage. Virtually they were a converted land plane with a pair of sea-boots stuck on in the most convenient place, and it appears to me that design has followed in the deep groove originally cut in attempts to improve this conversion.

Then there have been five years of controversy as to whether design should be considered from a sea or an air point of view, the loss meanwhile of the full encouragement and support of either faction being deplorable.

Then, and not last or least by any means, there is the fallacy which exists that the seaplane being a poor sort of aeroplane only requires a poor sort of pilot and only a pilot to handle it. If flying was all that was necessary he would probably meet requirements, for most types of seaplane are admittedly easy to fly once in the air, though cumbersome and slow on controls.

This armchair theory is unfortunately not borne out to anyone who cares to look up the statistics of seaplane accidents. Approximately 75 per cent. of the damage and 50 per cent. of the losses are attributable to accidents occurring on the water, and not directly due to engine failures, forced landings, take-offs, structural failures, etc., which account for landplane damage and losses.

It is extremely difficult to say with any degree of accuracy what proportion of seaplane disasters should be attributed:—

(*a*) To lack of knowledge in handling them in the daily varying conditions and circumstances.
(*b*) To limitations of design to meet requirements.
(*c*) To unavoidable circumstances.
(*d*) To errors of judgment which are almost inseparable from lack of knowledge.

From my study of the problems I estimate the proportions covering the whole field as:—

Lack of knowledge	45 per cent.
To design	25 ,,
Unavoidable circumstances	15 ,,
Errors of judgment	15 ,,

If my estimate of 45 per cent. is anywhere near correct (and perhaps one should allow a deduction of 15 per cent., the extent of a lecturer's licence) it is clear that until the users become more competent in handling seaplanes and assisting designers in gaining valuable practical information, so long will seaplane development be retarded to a serious extent.

The knowledge (I have described it as amphibious) which the seaplane pilot must possess to handle and maintain his seaplane safely in between flights must be kept ahead of or at least astride of design.

I feel convinced that seaplanes have a great future of usefulness before them to meet military and commercial requirements.

We are a maritime nation and have made greater strides with our surface craft than any other, and yet we are slow to realise the enormous future the seaplane holds out for speeding up the transport of mails, passengers and goods over the great ocean tracks where it will never be safe to despatch the aeroplane.

I do not claim like some enthusiasts to imagine that the seaplane of the future will be able to ride out the fiercest gale at sea, proceed on the water in all states of weather at the speed of a destroyer, and to rise in the air from the roughest sea. I do hope, however, to see the day when seaplanes are capable of linking up the great ports of the world and if forced to descend whilst en route of being capable of resisting destruction whilst waiting for the sea to moderate for repairs to be effected and for the flight to be continued.

However perfectly we design our seaplanes to meet these conditions they will be of little use until we know how to handle them.

We have never yet designed a fool-proof ship and still more difficult will it be to design a fool-proof ship that flies, but we need not make matters worse by failing to train crews to handle them on the water.

The fallacy I spoke of very generally exists and is deeply rooted, that a good land pilot, once he has taken a seaplane off and landed it successfully a few times and learnt its special peculiarities as a type, should also make an equally good seaplane pilot.

In so far as actual air pilotage is concerned, this is probably a truism, but unfortunately there is this other important side of the question to be taken into consideration.

Our eyes seem to be firmly shut to this fact and we allow the blame for accidents to be laid at the door of the strong wind, the rough sea, the weak mooring, the strong tide, the crowded harbour, and a dozen other reasons, which in reality all point to the want of knowledge by the pilot, which allows him to misjudge the action of these various causes on the seaplane. An accident occurs and everyone concerned enlarges on the difficulties and disadvantages of seaplanes; and the pity of it is that each accident puts another spoke into the wheel of seaplane development.

A pilot may choose seaplanes as his bent because he lives by the river or sea, because he is fond of boating and genuinely imagines he will like the life; perhaps because he finds an aerodrome a bit too small or a bit too hard for his liking and thinks the sea is a bit larger and softer. It does not take long as a rule to disabuse him on that score, and if he does have a forced landing out at sea and survives, he wishes it had been back on the aerodrome where it is not quite so wet nor so far from the sheds.

But now to return to my title, Airmanship at Sea, which I have seen travestied in quite good part with the last two words in parenthesis. As I have already tried to explain to you, this is not far short of being a true interpretation of the present day state of affairs when compared with the standard of airmanship with landplanes. I ask you, however, in all seriousness if wings were put on tramcars or railway trucks and land pilots were asked to stagger off any sort

of rough country in this type of aircraft, would not " at sea " in its metaphorical sense be equally applicable.

I am not really going to be so unkind to our striving pioneer seaplane designers as to liken our seaplanes to flying railway trucks, because they are not like them in the least to look at and it may give a wrong impression.

To explain, it is necessary to go back for a moment to the embyro stage. The aeroplane or landplane was evolved as such from its inception and was not arrived at by the conversion of a pram or bicycle into a flying machine. The present day seaplane is, however, largely the product of the evolution of the aeroplane super-imposed on a pair of floats or boat to support it on the sea.

The seaplane, which is so vitally dependent on its buoyancy, is a conversion of a surface craft into what is called a flying boat or float plane.

The whole has *not* been conceived from the start as a seaplane in *its truest sense*, and in my opinion this has been a great drawback resulting in our seaplanes being virtually what they are called, *flying boats*.

During the last few years some very considerable advance has been made in improving both the seaworthy and airworthy qualities of these craft, but a very great deal remains to be done before the term " *seaplane* " can really become applicable.

To come back to my title again, what does it convey to the lay mind? Probably it is thought to be the term used for flying over the sea. Really it is an advanced effort to describe the conglomerate knowledge required to manœuvre on the water and in the air a conglomeration of half boat and half aeroplane.

As science advances new professions spring up, but the knowledge required is generally an expansion or elaboration of what was already known. So we can say airmanship is merely an expansion of pilotage and equally perhaps an expansion of seamanship, and it follows, therefore, that the seaplane pilot must have qualified in both these branches.

Let me ask you to picture to yourselves, in order to illustrate the argument, the fate of a seaplane manned only by sailors taxying to a slipway, or a tramp steamer coming alongside a wharf if manned only by pilots. Personally, I think the slipway and wharf would win every time.

I want to draw a clear line of distinction between fine weather occasions when a flying boat is launched after engines have been warmed up, taxied down wind to a suitable position for taking off, taking off, flying, landing and proceeding to a buoy.

That is what we usually picture to ourselves when thinking in terms of seaplanes. It is comparable to flying off and landing an aeroplane from a land aerodrome. The seaplane pilot requires little special knowledge for such normal occasions.

I think it is fair to say that these normal occasions only occur on the sea for about one third of the year, the remainder being abnormal. Little difference occurs to the methods adopted on the land aerodrome in abnormal conditions; whilst on the *sea* a very great change takes place.

It is on these occasions that an especial knowledge, or appreciation, of the conditions and their effect on the seaplane is essential unless seaplane flying is to be severely and unnecessarily restricted.

A combined knowledge of pilotage and seamanship is required in a hundred and one different ways every day a seaplane is used, each day presenting different conditions. I feel sure I am expressing the views of the majority of experienced seaplane pilots, both civil and service, in saying that a sense of seamanship is as essential to their calling as pilotage, and that theirs has been acquired at the expense of considerable discomfort and risk.

Having so far very broadly explained what the term airmanship at sea implies; positively declared that a knowledge of it is essential to pilots to reduce to a minimum the risk of damage to and loss of aircraft; stated a lack of it is seriously hindering progress, I will now attempt to describe in greater detail the management of seaplanes, their shortcomings, our experiences with various types and how airmanship plays such an important part in their use.

Unlike its sister the aeroplane, the seaplane's trials and tribulations do not end with the safe alighting after flight and not infrequently it leaves one turbulent frying-pan to be assailed by an even more persistent and unrelenting fire. Most pilots have had those uncomfortable hours flying a heavy machine, when they would willingly shed their coats, and have heaved a sigh of relief when their wheels touched the aerodrome. Their responsibility virtually ended when the handling party took charge and pushed the pneumatic-tyred aeroplane twenty or thirty yards into its shed. But on a similar day the seaplane pilot, unless he were singularly fortunate in having sheltered water, which is the exception rather than the rule, would most certainly have shipped a sea or so in taxying to his moorings or his slipway, and would have to exercise considerable skill and judgment before achieving his object.

I have said that the handling of seaplanes on the water is largely a question of the expansion of the knowledge of seamanship. While this is perfectly true, in a broad sense, there are numerous ills which the seaplane must always be heir to, which are not encountered by the sailor.

It has been aptly said that mooring a seaplane is analogous to mooring a fully rigged ship with the sails set. Just as the seaman is not confronted with such a problem so is he not required to steer a steamship by an air rudder, or to manœuvre with an engine which cannot be conveniently stopped and most certainly not reversed.

The difference lies in the fact that although the handling of seaplanes on the water follows to a great extent the laws governing the handling of vessels, the natural means of controlling them depend on air rather than water forces in almost inverse ratio.

To a sailor it's almost like asking him to rub his waistcoat with one hand and pat his head with the other. Perhaps the nearest simile one can suggest to the seaplane is a motor auxiliary vessel with the sails always set, and the yards always rigidly braced for a wind astern and the spanker rigged to replace the water rudder.

I think the stoutest hearted mariner would be perturbed if told to manœuvre such a craft in a crowded harbour. It must be admitted that the comparison is exaggerated, but it will suffice to show that the problems encountered by seaplanes are far more comprehensive than usually classed under the heading "Seamanship."

Given plenty of sea room and relatively moderate weather, manœuvring a seaplane is comparatively easy, but in a crowded fairway considerable experience and judgment are necessary. Naturally pilots do not make a practice of entering crowded havens, but it can be done with success when necessity or emergency arises. Such difficult harbours as Penzance, Newhaven and Torquay I have seen navigated by large type flying boats threading their way between large and small craft and frequently lifting a wing to clear a dinghy or a buoy, the width between piers at the harbour entrance being just sufficient to allow the span of the wings sufficient clearance by a few feet.

Naturally the question of manœuvring a multi-engined flying boat on the water does not present the same difficulties as encountered by the single engine type, as the engines can be used as occasion demands for the purpose of steering.

Of the two factors which affect the manœuvring of the seaplane on the water

the wind has infinitely more effect than the tide, so much so that in the majority of circumstances the latter can be ignored. This is, of course, due to the large aero structure swinging like a weathercock to the breeze, while the small draught of the craft does not permit of the tide taking its full effect. Even in fast flowing tidal rivers like the Forth, Humber and Medway, a seaplane at its moorings will ride to a light wind of seven or eight miles an hour and stand up against the stream which may be running at a full four knots in the opposite direction.

This weathercock effect is the more pronounced when under way. When taxying into the wind it is possible to steer at a slow speed, say five knots, on a course within two points of the wind. As it is desired to alter course out of the wind so the speed must be increased and it must be maintained if the course is to be made good. The stronger the wind blowing the greater the speed necessary to steer at an angle to the wind. This speed has to be increased as the angle to the wind grows greater until it reaches a maximum when tail to wind.

In the case of multi-engined seaplanes a course out of the wind is maintained by running the engines to windward faster than those to leeward, but even so it is rarely possible to run tail to wind at a less speed than 15 to 20 knots.

All seaplane pilots remember their first efforts to make a machine taxi in the direction they desired, more especially those trained in the early days when the reserve of power was either slight or did not exist. There was an old Maurice Farman on a south coast training station which immediately it was launched made straight for an adjacent pier. The pier seemed to have some form of magnetic attraction, and the rudder was quite useless against this uncanny power. Crowds would collect to watch the agonised features of the gallant officer as the wings crunched against the piles. It was common in those days to see three or four machines stranded on the mud in the vicinity of the slipway to which pilots had directed their wellmeaning but fruitless efforts. The use of higher powered engines has given greater acceleration on the water and this has solved these earlier troubles.

The use of the water rudder in seaplanes has hardly helped matters and has been practically abandoned. Ailerons are of great value in manœuvring on the water, in fact when steering into a moderate breeze it is possible in certain types of seaplanes to alter course by their use alone two points to either side of the wind. They are further particularly useful when steering side to wind when the leeward wing tip float can be kept partially immersed by depressing the windward aileron, and thus assisting the machine from swinging into wind.

The remaining aid to steering at slow speeds is the drogue or sea anchor. This consists, as is well known, of a conical shaped canvas bag open at both ends and the larger end kept in shape by a strong stiff ring of wire or wood. The latter is joined by equal length ropes to a single rope connected at a suitable position to the seaplane. On being dropped into the water it causes considerable reduction in speed by the resistance it affords and thus tends to make a fulcrum about which the craft can be more easily turned.

It is the general practice to use two drogues, one on either side, but in some cases it is useful to have a drogue pulling only on one side. This practice is resorted to when taxying a twin-engine flying boat with one engine stopped, the drogue pulling on the side of the running engine to assist in keeping a straight course. In the same way taxying for a long distance, side to wind, when it is not desirable to go fast, as for example in a choppy sea, the pilot is greatly relieved by towing one or both drogues on the leeward side.

The present practice is for flying boats alone to use drogues for the purpose of manœuvring owing to the difficulties of hauling in the drogues when under way in float type seaplanes.

In passing it is interesting to note that experiment has shown that the most suitable positions for drogues to tow is just behind the step in the case of the flying boat. In this position the minimum of oscillation appears to occur and the drogue shows no tendency to leap from the water as frequently happens when towed by longer lines. The drogue is a particularly valuable piece of seaplane equipment.

Much of what I have described to you is, of course, applicable to the land-plane taxying on the aerodrome, and in fine weather with lots of room it is no more difficult, but when it has to be done in a fairway and the aerodrome rolls up in lumps with the wind against the tide and cork-like the craft swings, if left to every wave, matters take on a different aspect. It is under these circumstances that the experienced pilot is required in keeping a straight course and his seaplane and engines dry. The slightest misjudgment or over-correction in the use of controls or engines is followed by a cold bath of green spray down the pilot's neck and over his engines, with detrimental effects to both.

In coming up to a buoy or taxying to the slipway, precision in steering and estimating the correct speed of approach is essential. The buoy may be near a ship or a pier, where buoys usually are, with no room for a seaplane to turn between them, if the buoy is missed.

My object is not to enlarge on the difficulties or disadvantages of seaplanes, there are too many ready to do that at any time, but rather to show that although they exist they are not any more insuperable than those with which sailors have had to contend.

It is argued that it is impossible to expect a craft so light and frail as a seaplane to withstand destruction if forced to land in a rough sea and certainly impossible for it to take off in one.

It is on this peg of lightness and frailty that I hang my hat for the future of seaplanes.

The seagull or any other deep-sea bird sits on the roughest sea facing the wind and paddling slowly into it or holding his ground against the wind and scurry. His eye is always alert for the breaking wave that may wet his back which he keeps as dry as a board. The moment he sees a wave which he cannot ordinarily surmount he just spreads his wings for the fraction of a second to gain the lift necessary to float over it. He does not keep his wings spread all the time because it is tiring, but the seaplane can do so without any exertion, so has this advantage over the gull.

Now if you hold a seaplane against the wind, either by an anchor or by using the engines, you adopt the seagull's method of keeping dry.

I have known many occasions when this theory has proved true in practice, but two in particular are worth telling you.

During an experimental cruise in 1922 I had charge of four flying boats, three of which at the time of this occurrence were anchored in St. Mary's Roads at the Scilly Islands. A permanent ground swell appears to have taken up its abode in this roadstead, probably because it is almost directly open to the Atlantic where the Gulf Stream divides.

It came on to blow, and by night was blowing a gale in fierce squalls. Our anxiety for the safety of the flying boats, particularly for one which was in a rather more exposed position, increased with the force of the wind. The Parent Ship's searchlight was played on the flying boat anchorage at half-hour intervals, not because anything could have been done as no ship's boat could have gone to their assistance, but I suppose out of curiosity to see if they were still there. At times it was very difficult to see them at all through the driving rain and spray.

However, next morning they were all still there snatching at their moorings

in the still angry sea. On examination later the only water they had taken on board during this remarkable test was a quantity of rain water.

By some curious oversight the smallest of the three (the P.5) had ridden out the storm with side doors left open, which meant that there was a gaping hole of about 2ft. diameter on each side, only 18ins. above the ordinary water line when at rest. The perpetrators of this omission were admonished, but owing to the valuable information they had accidentally provided the matter was not taken up to higher quarters.

The second case was also not so very long ago, when it was most important for a flying boat to proceed from Felixstowe to Grain.

It was blowing very hard, about 50 m.p.h. The C.O. postponed the departure during the early morning owing to the gale, but later after much persuasion and because the flying boat belonged to the Development Flight, he at last gave consent for a start to be made, and came down to see it off.

The sea in Harwich Harbour, of course, never gets very rough, but there was sufficient that day to prevent the ordinary harbour traffic from plying, and it presented a sheet of white horses racing one after the other

Owing to the force of the wind we were able to test each engine to maximum revolutions whilst still at the buoy. As soon as ready we let go, the pilot opened up his throttles and before any of the crew realised it the flying boat was in the air, the driest and shortest take-off I have ever experienced.

To lend colour perhaps I should mention as soon as the C.O. arrived at the water front and saw the state of the sea he made frantic signals for return, which fortunately were not observed.

In recounting these reminiscences I have somewhat deviated to side issues, but I contend that had a boat with a hull the same size as the P.5 been moored out at Scillies during that gale it would in all probability have been swamped, and likewise if attempts had been made to cross Harwich Harbour in a craft of equal size it would have had a particularly nasty and risky passage.

Except in the case of light float types which can be easily launched or got in from a slipway, it is becoming more and more the practice to "moor out" seaplanes and to dispense with the use of motor boats as pilots become more skilled in manœuvring their craft and learning that most of the early troubles were born of inexperience and not all due to latent and mysterious defects in the seaplanes themselves.

The practice of "mooring out" seaplanes has done more to bring their potentialities before the public than anything else of recent years.

It has crushed the old theory that the flight of seaplanes is limited to only such places where special slipways are provided and large sheds and a big staff of personnel to handle them exists. Moored-out seaplanes are no longer dependent on the state of the tide and weather before they can be launched from the slipway, and are free of all the other complications and risks attending the old practice.

"Moored-out" seaplanes are ready for flight as soon as the engine and cockpit covers are removed and stowed away, and by taxying over to a sheltered stretch of water will often get an opportunity of flying off when the occasion would have been too rough to launch them from the slipway at all.

They can now proceed to any harbour which offers shelter to the largest merchant or war vessels.

It must be remembered that these harbours are not necessarily selected because big vessels require such good protection at anchor, but because it is necessary to keep up communication with the shore by harbour craft or with their own boats.

Owing to their light draft seaplanes need not be so circumspect in their choice of harbours, as they can penetrate into small inlets and creeks impossible for deeper draft vessels.

There are, of course, disadvantages in mooring out. The crews have to be taken out each day to them, refuelling has to be carried out afloat and deterioration is considerable, but I do not view these disadvantages at all seriously, as it is only a matter of time before "all metal" seaplanes will replace the present types of wood and fabric construction and the crews will live on board.

"Mooring out" does, however, demand a very much more extensive knowledge of airmanship or seamanship, whichever one prefers to call it, than was necessary before when the seaplane spent four-fifths of its life in the comfort of a shed.

He must now be able to handle the ancillary craft for getting out to his seaplane in all weathers, and for refuelling. He must learn all about the maintenance of his craft afloat and a great deal more about taxying, mooring and unmooring, and knots, bends and hitches than was ever necessary before. He must learn more and more to be independent of shore facilities.

For major overhauls and repairs they still have to be got on shore.

The operation of getting in and launching seaplanes is, I think, sufficiently well-known not to require an explanation of the method, but it always strikes me that if I were an examiner of a pilot's knowledge of airmanship I should give the prospective candidate for first class honours the problem of getting in a flying boat.

I should give him these conditions:—

Time—high water
Flying boat at buoy.
Tide commencing to ebb across the slipway.
Wind blowing on shore at 20 knots.
Motor boat available.
Side piers to slipway to assist.

If the feat was accomplished without any untoward incident I should pass him with flying colours, as combined in this operation are some of the worst pitfalls the pilot has to contend with.

Mr. Fairey has said "the present methods of handling seaplanes in launching and bringing them ashore can be described as deplorable. . . . For small or large types the method has hardly been improved in ten years." One is bound to admit the statement is true, and although various schemes have been mooted their cost is prohibitive as they cannot be standardised for all localities. For the present, therefore, there remains the necessity for skilful handling and experienced personnel.

A large percentage of my estimate of damage occurs whilst performing this operation.

The seaplane floating dock is the real answer to the problem. We have a dock at present which is invaluable for hull repairs and engine changing. As a first design it has met all expectations. My prophecy for the future is the scrapping of all present ideas of seaplane establishments and their place taken by mobile floating docks. These docks should be about three times the size of the existing type and each capable of maintaining a "moored out" squadron of ten large type seaplanes without replacement for at least a year, and with accommodation for the crews and repair party, all told about 100 officers and men; that is, if the flying boats by that time are not capable of housing their own crews.

I am not going to attempt to estimate the economy, efficiency, progress and mobility which this change would effect, but I think it is none too soon for the powers that be to consider it.

The existing seaplane dock is on the small size as it moves to the motion of quite a slight sea and docking becomes a somewhat precarious operation in anything worse. It conveniently lies head to wind unless there is a very strong tide. When a seaplane is to be docked, the tanks are flooded until the side walls are practically awash at the after-end. Trestles on which the seaplane rests when docked are correctly positioned apart on their transverse rails. The seaplane then taxies up to a line streamed astern on a buoy which is picked up and made fast. Engines are switched off and the seaplane warped into position over the trestles. Quick-lifting chocks on the trestles are then operated to take under the chocks on the seaplane. The dock is then blown until the pontoon deck is dry. It is then possible to examine the whole of the bottom of the hull. Derricks are fitted to facilitate lifting out engines and in this and other respects the dock is better equipped than most sheds; indeed, a flying boat has been docked, had an engine changed, and been in the air again in sixteen hours.

With larger docks greater steadiness will obtain, and if some form of stern gate is fitted to prevent the sea waves entering, the movement between dock and flying boat, which is so difficult at present to control whilst docking, will probably be sufficiently minimised to render the operation one of ease.

These docks will have their own motive power and may eliminate bases, except perhaps for complete overhauls and where reserves are stored.

I read an article in "The Aeroplane," of 16th January, on "The Development of Flying Boats," with great interest. It referred to the activities of the British Marine Navigation Co. and the development of the Marine Airport at Woolston.

Although there is considerable advantage in being able to embark the passengers and goods direct from the shore base, I am inclined to think this company, as their aircraft grow larger, will soon launch out into a floating base, perhaps connected to the shore by a pontoon bridge.

Mr. Scott-Paine, in the same article, is reported to hold the opinion that "Launching and handling crews can be whacked into shape easily and so can maintenance men, but the difficulty is, that in spite of all our big flying boat patrols during the war, it is most difficult to discover a man who is used to the handling of seaplanes, launching, slipping, repairing, or salvaging."

Mr. Scott-Paine is lucky, as once he has given a dozen of his men the whacking he refers to, I presume he is able to keep them. Unfortunately it is not so easy in the Service as regulations forbid this method of instilling knowledge, and even if it permitted it would be a continuous performance owing to the number of men that pass, of necessity, through a unit in a year.

Naturally since so much time is spent at moorings especial care is necessary in their choice. Even people who ought to know better treat this matter in the most casual manner and have offered the flimsiest of anchors for mooring seaplanes. At a time when our chief endeavour in the development of seaplanes is to make them independent of big shore depots or bases the greatest difficulty, and one that we have not yet surmounted, is to provide them with suitable mooring equipment sufficiently light to take into the air and strong enough to hold in a breeze. When it is realised that fifty pounds would be considered an excessive allowance for an anchor the difficulty is apparent. Even if a heavy anchor were permissible there are other obstacles to contend with. Perhaps the following incident, which occurred some months ago, will make this clear. An officer was taking a new type of flying boat on an extended cruise and it was necessary to have ballast of over a hundred pounds in the bows to replace armament which had been temporarily removed. He decided that rather than take sand bags he would have a good useful anchor. Accordingly he unearthed a one-hundredweight mushroom anchor and placed it beneath the bows of the machine as it rested in

the shed. Next with his crew of three he climbed into the boat and hauled up the anchor. Unfortunately he had not reckoned on the awkward shape of the bows, and the united efforts of the struggling crew could not get that anchor into the flying boat. Thus it will be seen that an efficient anchor of orthodox design would require some special device such as a davit and winch to make it workable. At the present time moorings are laid for seaplanes by marine craft, and unless some entirely new principle is evolved I cannot foresee the cutting of this last link which holds out against the complete independence of the seaplane. Opinions differ somewhat among seaplane pilots as to the types of buoys they prefer, but all are agreed that the sinker or anchor should be as heavy as possible. I know one pilot who, when visiting a strange harbour, invariably moors to the largest buoy which is available. His argument is that the bigger the buoy the bigger the anchor. This naturally is not always good for the bows of the seaplane; but then to continue his remarks when criticised "a dented nose on the sea is better than a scrapped hull on the beach." Unfortunately, the apparent axiom concerning the proportions of buoy to anchor is no more reliable than the information proffered by the local seamen, who invariably assure you that the mooring under discussion will hold a battleship.

During the summer of 1922 it was necessary to shelter a seaplane in a harbour on the south coast, and after consultation with all the local experts the machine was made fast to a very serviceable-looking mooring. During the night a fresh breeze sprang up, and the watchman called the pilot to report the seaplane as missing. A small motor boat was obtained and the seaplane discovered at the other side of the harbour entrance grinding its tail against a pier, having dragged the mooring buoy and what was afterwards discovered to be a mass of dredger mooring chains with it. Although it was surprising that it should have dragged such a quantity of mud-sunken heavy chain, this is what the local pilot and fishermen and harbour master estimated was sufficient to hold a battleship.

During the recent visit of two F.5 type flying boats to the Gothenburg Exhibition the Swedish Naval Air Service welcomed them most hospitably to their seaplane station, and went to very great trouble in laying moorings, it having been explained what a heavy anchor was necessary. During the first strong breeze both flying boats dragged their anchors within a very short distance of a breakwater, so still heavier anchors were laid of the early sailing ship pattern weighing about eight hundredweight.

The first gale that followed saw one of the boats drag its moorings across the harbour on to the breakwater, where the tail and rudder were severely damaged.

There is something almost uncanny about the drag a seaplane exerts the size of a large flying boat, and I estimate that in a wind of 65 m.p.h. it is somewhere in the region of 600 horse-power by a boat of the F.5 type.

Permanent moorings for flying boats should weigh not less than a ton, temporary ones not less than ten hundredweight, and when the latter are used, at least double the length of mooring chain is required if any margin of safety and peace of mind is desired.

The buoy chosen for mooring is usually small. It may be a metal cylinder, barrel or cork buoy provided with a ring on top for picking up with the boat hook. It is the practice to make fast direct on to the mooring wire beneath the buoy, this wire being made fast to the buoy's eye when not in use. Taking the strain direct from the anchor prevents the possibility of weakness in the buoy's fittings. It is an advantage to have the buoy sufficiently light to lift into the machine, as this prevents the danger of the seaplane rubbing against it. However, in strong tidal waters this is impracticable as a light buoy will be submerged by the current.

Personally, I advocate the use of any buoy which has a weighty enough anchor attached to it and has sufficient clear space for the seaplane to swing round it.

I have seen reports of damage caused to the bows of seaplanes after bumping against large buoys, but I assure you it can be avoided by the judicious use of drogues, ailerons or fenders if necessary.

It is only in dead calms, a complete change of wind, or when the wind and tide in opposite directions exert an equal pressure that the seaplane gets a chance of riding up to the buoy. Large buoys are difficult to get clear of in the ordinary way, as they will not pass under the wings. In that case the seaplane should be secured by the tail to the buoy when it is desired to leave it; engines can then be tested to full revolutions, the tail line cast off and the seaplane has a clear passage away from the buoy.

Flying at moorings is a possibility in wind speeds equal to flying speed, but this can be prevented by breaking the lifting effect of the lower plane by stretching strips of canvas vertically along the upper surface of the plane attached to the struts.

Since the drag of seaplanes in a strong wind is so great, the method of securing it to the mooring chain is of necessity somewhat elaborate.

In flying boats a slack wire cable is fitted from a metal eye where the keel joins the nose to a similar fitting some eight feet further aft on the keel. Along this cable slides a ring holding a short wire which is to be joined to the mooring. The object of the sliding pull is that the hull can move freely to the sea and wind in a vertical plane and avoid sudden strains. When strong winds are probable, a further arrangement known as the "Yarmouth" mooring gear is fitted. This consists of wire strops from the base of the forward struts of both engine mountings connected together to the moorings. In practice it is usual to arrange the "Yarmouth" gear so that it takes the strain at the same time as the wire from the nose, more popularly called "the towing pennant." The Yarmouth strop is also used when the seaplane is to be towed at speed for any distance.

This side of the subject also covers too wide a field to describe all the other points in such detail, but such items as re-fuelling, towing, action after forced landings, beaching for repairs, salvage, assisting another seaplane in distress, getting on board in rough weather, docking, maintenance and preservation of moored-out seaplanes, all require intimate knowledge of airmanship, which can only be acquired by long and continuous experience in handling seaplanes on the water in all the varying conditions with which they have to contend.

The life of a seaplane's crew is an arduous one. There is little joy in flying such heavy types of aircraft, and in the case of seaplanes only very rough comfort. More often than not they start a long flight soaked to the skin. On alighting and arriving at the buoy they frequently spend half an hour or more tugging and hauling on ropes and wires whilst mooring up, but there is something about it all which is attractive and appealing. Probably it is the ever-varying combination of events which go to make up the day's work of a seaplane's crew.

There are few voluntary reversions from the seaplane side to the land side, although flying is the common incentive to both.

In conclusion, I must take you back to my estimate of the damage to seaplanes which occurs on the water, so largely the result of inexperience and lack of appreciation of cause and effect of the combined elements on the part of those into whose hands seaplanes are entrusted.

I hope I have been able to convince you that there is a vast difference between the handling of seaplanes and aeroplanes prior to flight, and that it does not follow therefore that a good land pilot is necessarily a good seaplane pilot.

I hope also that I have been able to convince you that although this difference exists, it should not be the cause of any want of confidence in the future possibilities of seaplanes. Such difficulties as exist lend themselves to removal if treated by experienced hands.

Such long flights as have been already carried out successfully in the Mediterranean in the old F type flying boats go to prove what may be expected in the near future.

Flying boats have flown from Malta to Constantinople, Gibraltar and Alexandria, involving flights of 1,500-2,000 miles. Tests have been carried out in home waters of flying boats proceeding on endurance trips away from their base up to six weeks with satisfactory results.

New type seaplanes, both float and boat type, are being designed, but we only have the old stagers left to fly them.

Fresh blood is required to replace them, but before this can be done effectively they should be trained from the start as seaplane pilots and grow up with the salt of the sea in their nostrils if full value is to be obtained from the flying boats they handle and for the development of the world-wide types to follow.

I must thank you all very much for listening so attentively to this long paper, and I trust that in pointing out some of the difficulties we have to face in handling seaplanes that I have not overdone it and that you will feel no less convinced than myself that they will largely disappear as experience is gained. That seaworthiness will be improved is undoubted, but the power to stop in the air for long periods at economical speeds must be the inevitable goal to which we must aim. The future of the seaplane and flying boat rests on its power to work with the minimum shore organisation, its power to establish a base at the shortest notice wherever ships can be safely anchored and its power to resist destruction when forced to descend at sea. In these respects it holds a unique position which its sister the aeroplane cannot hope to contest and it is along these paths which research and development must walk hand in hand before final success is achieved.

Discussion

The Chairman, commenting on the applause which followed the reading of the paper, said it indicated how very interesting it was; this applied not only to the paper, but also to the slides which had been shown. Although, he said, seaplanes had very many disadvantages, there was one thing in their favour, namely, that they could be made large, and could be heavily loaded in an aerodynamic sense to a point that he saw no likelihood of being possible with aeroplanes. Progress in the design of seaplanes was, naturally, very slow, because of the greater difficulties of the job, and, of course, during the war, when progress in design was going ahead so very fast, the thing to do was to get along on the lines which gave the quickest returns. What he felt was that it was not yet possible to say what was the correct general line that seaplane design should take. At least, he did not know it, and he had never felt that any design which had been put forward was quite of the right general type. He believed that was a fairly common view amongst most people who had had much to do with design or operation. The remark which Squadron Leader Maycock had made with regard to seagulls had a bearing on this question. If a seagull were able to keep afloat with such comfort on the surface of a rough sea, that might give some indication of the future development of the seaplane; whereas the seagull had to spread its wings when it wanted to ride over a particularly rough piece of water, the seaplane had its wings spread all the time. There was one main difference between a seaplane and a seagull, namely, that the seagull had no long tail behind, and had not the elaborate structure of a tail plane and rudder, which structure frequently got the seaplane into trouble. In conclusion, the Chairman said there was one member of the audience that evening who had had a unique experience

of airmanship at sea, in connection with the trans-Atlantic flight, and he hoped he would say a few words as to what happened on that occasion, because the experiences met with were not common knowledge, at least in this country, but they were most striking and interesting.

Commander TOWERS said he appreciated the invitation which the Chairman had extended to him, but had not come to discuss the flight mentioned, because it did not come quite under the subject of Squadron Leader Maycock's paper; the experiences were essentially those met with in the open sea, which were quite different from those met with in port. However, there were one or two points which might be of interest. A statement had been made that the seagull could ride very comfortably on the sea. With regard to the seaplane, however, in his opinion the question of comfort when down on the sea, whether taxying or riding to a sea anchor, was one which was largely dependent on the relative size of the sea. When he and his colleagues in the N.C.3 came down off the Azores in order to get a radio compass bearing, there was a very dense fog, and they could not see the condition of the sea until it was too late to pull up. There was a very heavy sea. A seventy-mile-an-hour gale blew for 2½ days, and the greatest difficulties arose when the sea was building up. Finally, the waves reached tremendous heights, and they were so large relative to the size of the seaplane that it went up and down just as one would go up and down hills in an automobile. That was pretty much the position of the seagull, which was very much more disturbed on ripply water than in a heavy sea. The same was true of a seaplane. He did not mean that the seaplane was uncomfortable on ripply water, but in a choppy sea the seaplane was in a worse position than in a really heavy sea, when the waves were tremendous. That did not apply in landing, nor did it apply in taking off, but those conditions did apply to himself and his colleagues, and there was no doubt that, had not the wind increased in force and enabled them to make their way eventually on these tremendous waves into the lee of the land, they would not have survived. The fact that the sea had got so bad had saved their lives.

Wing Commander T. R. CAVE-BROWNE-CAVE said there were many pilots present whom he was very keen to get into action, and, by way of goading them into speech, he would try to say something which, though in his view strictly true, was sufficiently controversial to bring them to their feet.

What the seaplane suffered from most was that people did not realise the difficulties of the problem. Many considered that if they had some experience of seamanship and flying they were *ipso facto* seaplane pilots. That was wrong. The seamanship that was required in order to work flying boats effectively was altogether different from seamanship as commonly understood. In fact, he was not certain that if a man started with a knowledge of ordinary seamanship he did not start with a handicap, in comparison with one who had no knowledge of seamanship at all, because his difficulty was to realise the differences.

Squadron Leader Maycock's lecture was a strange mixture of pessimistic expressions and descriptions of actual achievements which he believed everybody must regard as remarkable, and certainly encouraging. To see a really experienced pilot handle a flying boat produced admiration in everybody. He had had quite a lot of experience of that at Grain. He believed that the difficulties of working seaplanes could be got over if we expended on them anything like the amount of energy and talent which had been expended on the aeroplane. The seaplane had difficulties of its own additional to those of the aeroplane.

Seaplane and flying boat pilots were much more long-suffering than were their aeroplane brothers. The seaplane was an unhandy thing; it was much harder work to fly it. The personal discomforts connected with it were often great. Anybody who persisted as a seaplane pilot was such a long-suffering individual that he did not complain constructively about the experiences he under-

went. Therefore it was difficult for designers to realise exactly what was required to improve matters. That was where Squadron Leader Maycock had done such signal service, not only to the Society, but to aeronautics at large, in putting his experiences on record. He had done as much as anybody actually to get these problems solved in practice; not only that, but he had taken the trouble, although very busy, to write these things down. He (Wing Commander Cave-Browne-Cave) was sure that the Society was very grateful indeed to him.

There was one difficulty in connection with the seaplane which he was afraid was rather fundamental. It was designed to be an aeroplane, and also to be seaworthy on the water. The difficulty was in building the aero structure sufficiently light to fly and sufficiently strong to resist blows of water and spray. That was a very great difficulty. The density of water was about a thousand times that of air, and so long as the aero structure was reached by water and spray it would be likely to break up. He thought the remedy was so to design the aircraft that the aero structure never came into serious contact with the water.

There was a table in the paper in which the author had analysed the causes of failure of seaplanes. That table was rather interesting, and he thought correct, in attributing 45 per cent. of the calamities to lack of knowledge. Without being unduly critical of pilots, he (Wing Commander Cave-Browne-Cave) did suggest that that was about right. The use of the term " lack of knowledge " was not, perhaps, the kindest way in which to express it; it was sheer lack of " experience." There had not been a sufficient number of seaplane pilots engaged on seaplane work for a sufficiently long time to acquire the necessary knowledge. It was very difficult indeed to acquire, and was altogether additional to the knowledge required for aeroplanes. As soon as the energy to acquire this knowledge was available, the progress of the seaplane would be, he believed, correspondingly rapid.

Major Brackley said that Squadron Leader Maycock's excellent paper had interested him very much. The lecturer had shown very vividly a number of the difficulties which went to make the life of a seaplane pilot worth living. He had shown clearly the difficulties met with in some types of sea-going aircraft, both with regard to handling on the water and on the land. Of course, it was admitted that the actual flying difficulties were the least of all. After considerable experience of the sea-going side, he himself had only recently returned from Japan, where, with the British Air Mission to the Imperial Japanese Navy, he had been tackling the problems of training personnel for all branches of naval air work. Although they had pukka naval officers and ratings to deal with, they had the same difficulties over there as were experienced in the naval side of the Royal Air Force to-day. It was difficult to make the higher command realise that flying personnel could not be trained in a few months (and in Japan the Navy has control of its Air Service). Although they might be trained mariners, it did not follow that they would necessarily make good airmen at sea, and, having once got them to a state where their experience could be usefully employed in building up the service and training the young idea, they should not be posted to some other job entirely disconnected with naval air work. It was, indeed, very surprising that such good results were obtained in the two and a half years during which the Mission was in Japan.

Major Brackley was sorry that the lecturer had not touched upon amphibians, or airmanship at sea with regard to aircraft carriers and deck work. As far as the handling of big flying boats was concerned (or small ones for that matter), it seemed so obvious that many of the difficulties would be overcome by improvement in design and fitting of some form of amphibian gear to do away with the horribly cumbersome and inconvenient trolley for getting in and out of the water. There was much scope for designers if they could only be encouraged by those in authority. After considerable experience of amphibians—and a good many wet shirts—he had become a firm believer in their future, although at present there

is much room for improvement. He looked forward to the day—not far distant—when we should have a really seaworthy, airworthy amphibian capable of alighting on and taking off from the deck of a liner, or alighting on and taking off from a rough sea. Surely that was not asking too much of our designers.

Flight Lieutenant B. C. H. Cross, D.F.C., said that airmanship at sea, and all that it implied, could be learnt only from practical experience. The individual lessons learned from a multitude of minor misfortunes went to make the pilot's experience. A capacity for making mistakes, together with the power to observe and analyse their causes to prevent their repetition, was the essence of a seaplane pilot's training.

There was one thing he would like to ask the lecturer, and that was—what was the ultimate goal we are aiming at with flying boats and seaplanes? It appeared that the flying boat had become very nearly independent of shore bases. The lecturer had shown that it was only the question of designing a suitable anchor which prevented the flying boat being free of outside aid and working from almost any harbour. Even such tiny details as a self-charging electric mooring light and a small dinghy had been provided. He suggested that in the near future flying boats would be capable of working from an advanced base for prolonged periods, without sheds, and motor boats—which latter were an ever-present curse—and supported only by a trawler carrying fuel and oil or preferably by a floating dock. This was an objective which no aeroplane could hope to attain, and was among the strongest reasons for pushing ahead with seaplane development.

Squadron Leader Maycock, replying to the discussion, said that Wing Commander Cave-Browne-Cave had put what he (Squadron Leader Maycock) had been trying to get at very much more clearly than he was able to do himself. He agreed that, to a large extent, we must try to separate our aero structure from the sea structure. If seaplanes had been designed from the embryo stage, he believed that that would have been done. We should have had the sea structure very different from what we have actually got at present, and the aero structure would have been, or perhaps could have been, of lighter construction than it is now. It was rather difficult to see how it was possible to prevent the aero structure coming into contact with the sea. However, that was a line of thought which we should follow up.

He was glad also to see that Major Brackley's views coincided with those which he himself had tried to express. He valued Major Brackley's opinion because he had read of the doings of the British Air Mission in Japan, and realised that they must have had quite as much as or even more difficulty than we had had here, because they had covered very much greater distances. In fact, he believed they went right round Japan on one occasion, and very difficult circumstances must have arisen on such a long cruise; as Flight Lieutenant Cross had said, we should learn more by our mistakes in connection with these little incidents than from anything else. It was rather difficult to explain airmanship at sea. However, it was certain that seamanship could not be learned from a book, and that it was only by continual practice that we could hope to become perfect in airmanship.

Reference had been made by Commander Towers to his (the lecturer's) theory of the seagull. He agreed absolutely with Commander Towers, and in condensing the paper had omitted reference to the fact. The comfortable riding of a seaplane on the water was absolutely a question of the size of the sea in proportion to the size of the machine. The most dangerous sea was that met with at the mouths of rivers and such places as that, where the wind was blowing hard, perhaps, against the tide, and the size of the sea could not become proportional to the force of the wind. Commander Towers' escape whilst the sea was mounting up proved

what a seaplane could successfully stand in the open sea. In harbours or estuaries there was a lift from the planes, but it was not always sufficient to take the machine clear of the water, and the little waves broke all over it, whereas, if the seas were big, the machine would float over them quite comfortably. He believed that that was what happened at the Scillies, because there they were open to the Atlantic. There was a big ground swell, and the machines rode up over those ground swells in perfect comfort, although the sea was rough in addition.

Dealing with Flight Lieutenant Cross's question as to what our aim was in connection with big flying boats, the lecturer said it was difficult to say. Until we really showed what flying boats could do, the demand would not come out, but as soon as we could fly from here to there without requiring a big organisation, he believed we should very soon find that the demand would arise, both from the military and the commercial points of view. But flying boats had already done quite good military service during the war, and the marine air port at Woolston is going ahead, the air line to the Channel Islands having actually started. He believed that in time we should find that these air liners would be capable, for example, of flying to the Mediterranean or down the west coast of Africa, going from port to port, and he saw no reason why they should not. People would want to get from place to place much more quickly than they can in steamers, and when seaplanes are able to carry on that work safely and consistently, the demand will certainly arise.

In elaboration of his reply, Squadron Leader Maycock has forwarded the following note :—

The " seagull " theory is based upon the fact that in rough weather it always heads into the wind and spreads its wings to gain lift to rise over broken water but does not necessarily " take off." Probably if it was not tiring to the seagull it would keep its wings always spread whilst on the water, as the seaplane is constructed to do.

It is agreed that the comfort with which a seaplane will ride on the water is largely a question of proportion between the size of the seaplane and the size of the sea. A third factor, the force of the wind, has to be taken into consideration.

It will be agreed that if a seaplane (which can rise from the sea with an air speed of 60 m.p.h.) is held against a wind of 60 m.p.h., its displacement of water will be very much less than if there was no wind. If this is accepted, it will further be agreed that a seaplane, so long as it is kept head to a 60 m.p.h. wind, will be proverbially like a cork on the water.

From this point it is necessary to divide the question into two parts, *e.g.*, (*a*) open sea, (*b*) sheltered water.

Open sea.—In the open the sea normally rises in proportion to the force of the wind, but naturally is somewhat behind the increase in the wind, which is a slight advantage to the seaplane. This statement must not be confused with the fact that a swell usually precedes a storm and serves as a very useful indication of an approaching gale in exposed places, such as the west coast of Ireland.

It is the contention that a seaplane kept head to wind in an increasing wind and rising sea is better able to surmount the sea than the ordinary surface craft of its own size.

Damage to wings and tail structure from the effects of the rough sea have not been taken into account, as that is largely a question of control and physical endurance and does not enter into this particular theory.

That this contention can be substantiated in practice the writer is satisfied, but to make it clear on paper is no easy matter. Possibly the following table will be of use, but the figures given are purely hypothetical.

Wind velocity in m.p.h.	Height of waves in feet.	Lift of planes in lbs.	Displacement of seaplane in lbs.
Nil	Calm	*Nil*	12,000
10	2—3	1,000	11,000
20	4—6	4,000	8,000
30	8—12	6,500	5,500
40	15—20	9,000	3,000
50	25—35	10,500	1,500
60	35—40	12,000	*Nil*

The most uncomfortable conditions shown in the table are in wind speeds betwen 18-30 m.p.h., when the height of waves is small, and the lift between one-third and one-half of the total weight. If the seaplane's engines can be used to increase the wind speed and so increase the lift, this critical period would be eliminated to a considerable extent.

In sheltered water.—Sheltered water provides a variety of conditions impossible to classify here, which affect the comfort of the seaplane on the water.

To briefly illustrate the difference between open sea and sheltered water conditions, the simple case of a bay such as Torbay or Weymouth will be taken with the *wind off the land*, which is frequently the case, as the bays are land-locked on three sides.

The above table can be taken except that the height of the waves will not increase over about four feet whatever the force of the wind, whilst the lift will be seen to remain insufficient to reduce displacement appreciably until it is blowing 50 m.p.h. Four-feet waves in sheltered water are not produced until there is a wind force of about 30 m.p.h. The great difference lies in the fact that the open sea wave of four feet is produced by a wind of 15-20 m.p.h., and is composed of heavy water with long intervals between, whilst a wave of equal height in harbour requires a wind of 30 m.p.h. and is hollow and broken and has short intervals, and is driven with considerable force behind it.

Under these conditions the most uncomfortable period for the seaplane is in wind speeds between 30-50 m.p.h., but again the use of engines will eliminate it to a considerable extent.

The correctness of the theory is entirely dependent on the pilot's ability to keep the seaplane head to wind and to hold it against it with anchor or engines. It was put forward to substantiate the writer's belief that seaplanes are capable of withstanding destruction if forced to land at sea. On first thoughts, Commander Towers' remark that the comfort of a seaplane on the water was a question of proportion of size of the sea to the size of the seaplane was agreed to without reservation. It is now hoped that the above will throw some further light on the point.

It may perhaps be taken as an accepted fact that in rough weather a seaplane will ride less comfortably in sheltered water than on the open sea, which is somewhat of an anomaly, but to the advantage of the seaplane.

Can there be any doubt that the aero structure does materially assist the hull of the seaplane in surmounting rough seas? I think experience has proved conclusively that it does.

The seagull and the seaplane have tail aerofoils, but they only use them when on the water for " taking off "; at other times they both carry them well clear of the sea.

A hearty vote of thanks was accorded Squadron Leader Maycock at the close of the discussion, and the meeting closed.

Flight Lieutenant G. MORNINGTON BRYER (*contributed*): The difficulties involved in handling seaplanes occupy much of Squadron Leader Maycock's valuable paper "Airmanship at Sea." Nearly all of those difficulties hinge upon the fact that the seaplane separates from its shore-going wheels when taking to the air. If, however, a seaplane is made to retain its wheels and become an amphibian, most of its troubles in going from and returning to its hangar disappear at the cost of some slight loss of performance. This loss may be compensated by other advantages. The amphibian is able to taxi up any suitable beach in the event of bad weather approaching, or to effect a repair, or to drain or clean fouling from the hull. On the score of operational cost the amphibian is in a favourable position compared with the seaplane.

Large amphibians cannot be expected at present to be capable of using aerodromes for regular landings, not only because of the structural difficulties involved, but because of the small number of suitable aerodromes and the hazard of a forced landing on unsuitable land. This consideration may be sufficient to rule out rubber tyres and their inherent disadvantages.

It therefore appears that the most promising line of development for sea-going aeroplanes is that of the amphibian. Had seaplanes possessed utility and independence comparable with that of contemporary land planes, the rate of development in seaplane design would have been much more rapid.

With the amphibian will come amphibious knowledge (to the lack of which Squadron Leader Maycock attributes nearly a half of the number of seaplane disasters), and through the amphibian will come the ultimate truth that the air has no coastline. To separate the land from the sea and to compel the airman to be dependent upon either one or the other is to deprive him of half his heritage.

Mr. T. H. NARBETH (*communicated*): May I say at once that it is a matter of great encouragement to all interested in the future of aviation that the Air Ministry has permitted an officer having full official knowledge, together with wide experience and great ability in his vocation, such as Squadron Leader R. Maycock, O.B.E., R.A.F., is known to be, to come forward and give his views so definitely and in such great detail. This paper, taken in conjunction with the very suggestive paper given by Wing-Commander T. R. Cave-Browne-Cave, C.B.E., R.A.F., on 15th February, 1923 (see Journal, June, 1923), shows what great funds of knowledge and experience are necessary for the successful development of Seaplane and Flying Boat Services. It also confirms the opinion that the Air Ministry was fully justified in joining with the Admiralty to carry out the flying boat manœuvres on the South Coast in 1922, using the combination of H.M.S. "Ark Royal" and the seaplane dock as a mobile base. There can be no doubt that the expenditure of money incurred was timely and wise, and that it has yielded handsome returns in various ways. It is to be hoped that such manœuvres will become annual functions and will, at times, be carried out in localities where larger numbers of the British public can see something of the actual performance of the flying boats and take a more active and intelligent interest in the work while it is in progress. Wherever economy is exercised it is to be hoped it will not be on matters like this which provide pilots and constructors with most essential information.

Experience in the handling of sailing boats convinced me long ago that the quality so well summed up by Squadron Leader Maycock as the "Sense of Seamanship" is a matter of the first importance for all seaplane pilots, and also for all pilots who have to handle landplanes over the sea and alight upon ships. I have often seen boys handling sailing boats in gusty weather with ease and safety, while their elders, who had considerable knowledge of the scientific questions involved, but less practical experience, found themselves in difficulties. Skill in sailing small boats would be such a valuable asset to every seaplane pilot that

I often think it most desirable that his training should begin in that matter so that the "sea sense" might actually predominate over the "air sense" in his mental make-up. Such a procedure would also serve to weed out at an early stage young pilots who would never have any hope of successfully handling a seaplane, although they might become proficient as pilots for landplanes for overland services. This may perhaps be open to objection because of increased cost, or longer period of training; but even so there is very good reason to believe that they would be much more efficient as seaplane pilots by the time they had finished their flying training, *i.e.*, a better article would be provided for the extra cost, etc. There is however a much more important reason for this course; I fully believe that we shall soon see very much larger flying boats in common use, and the officers in charge of them must be first rate seamen. The boats must carry some life-saving craft and the wing floats have already been suggested as suitable for the service. With wing floats developed into useful sailing or motor boats, the flying boat gets its own means of communication with the shore, etc. The carrying of such boats and the conscious possession of skill in seamanship and boat handling would be two factors of great assistance to pilots called upon to endure the great strain of prolonged and lonely oversea flights.

The paper teems with suggestive sentences and ideas which will provide matter for thought perhaps for years to come. Details were no doubt discussed when the paper was read and some of the following remarks may therefore be redundant.

Squadron Leader Maycock touches upon questions of design at several points commencing with that of seaplane floats, upon which he is rather severe. It is no doubt true that badly designed seaplane floats were added to aeroplanes by some aircraft builders without much nautical knowledge. The advantage of an aircraft designer being in the first place a naval architect were set out in a paper on "A Proposed Aircraft Carrying Mail Steamer," which I had the honour to present to the Institution of Naval Architects in 1923 jointly with Sir Eustace d'Eyncourt. The gain is much greater in the case of seaplanes, but for the production of successful flying boats the combination of the skill of the aircraft designer and the naval architect is essential. The advantage was well shown as far back as 1913 when Messrs. J. S. White and Co., of Cowes, built seaplanes combining the skill of Mr. Howard Wright as aircraft designer and Mr. John Smith as designer of floats. The very beautiful twin floats thus produced embodied many of the features which contributed to the great success of the U.S.A. seaplanes in the Schneider Cup Race of 1923. Space will, however, not permit me to enlarge as I should wish on the details of float design.

On two matters of design of flying boats arising in the paper I should like to make suggestions to lessen some of the difficulties referred to by Squadron Leader Maycock:—

(1) Docking would be greatly simplified, and damage during landing and handling ashore much reduced, if the flying boats could be built with two robust parallel keels, straight for some distance before and abaft the centre of gravity of the whole machine. In twin-engined boats it would be a further advantage if these keels could be vertically directly beneath the main engine bearers. The whole of the framing of the boats should be designed to radiate from these parallel strong members. This arrangement would permit of using trolleys having flat tops, and then exact alignment of the flying boat in position on the centre of the trolley would not be necessary. Hauling lines carried out through sheaves on the trolley could be attached to small floats, picked up by the flying boat, and made fast at suitable positions. The boat could then be hauled into position on the trolley and up the slipway after grounding on the trolley without the need of waders or side walks. Rapid and safe launching would also be facilitated.

(2) With increasing sizes of flying boats efficient control for manœuvring

in harbour will become of increasing importance. This can apparently only be achieved by the use of forces derived from the water instead of from the air, and it appears most desirable to test the value of a screw propeller working on a shaft geared down from the engine shaft in a suitable manner, and fitted with a friction clutch; and also to fit "kitchen" rudders for trial in association with such propellers.

Water rudders which are dependent upon the speed of the flying boat through the water for the development of steering forces are quite illusory, but on the above plan the stream from the water propeller will supply force for steering quite apart from the speed of the flying boat, while the kitchen rudders will not only steer, but can give a thrust ahead or astern as desired, while the engine driving the airscrew continues to run in the same direction. Under many circumstances the air propeller, acting as a windmill, would probably provide the power necessary for driving the water propeller and for manœuvring up to the mooring, etc., by the means proposed.

The alternative method in use by the Supermarine Co. at Woolston, by which the use of a trolley is entirely avoided, also seems worthy of consideration for places in which a hard sloping beach extended throughout the whole range of the rise and fall of the tide can be provided. The machines are amphibian, the wheels are let down after alighting on the water and the machine taxies right on to the slope from whence it is hauled. The experience obtained at Southampton, however, appears to indicate the soundness of Squadron Leader Maycock's view that the services should be carried on without removing the flying boat from the water and that actual grounding of the boat should be an exceptional event. The experience of the U.S. Airways Co. also points in the same direction.

Reference has been made in the paper to the need for heavy anchors and to the rather astonishing drag reported. This effect may perhaps be explained when the flying boat is anchored in a good wind with a fair sea running, as follows:— The mooring line is so light and so short that it hangs as a catenary direct from the flying boat to the mooring so that the pull at the mooring tends (i.) to drag and (ii.) to lift the mooring. As a sea passes there is a sudden and greatly increased *lift*, and as a result the pressure of the weight of the mooring on the bottom of the sea is thus momentarily greatly reduced and the mooring gives a hop. It would perhaps be worth considering whether a strop with a fitting like an Oleo shock-absorber could be fitted so as to permit of a little see-saw and thus prevent this hopping action.

If the flying boats are moored with the tail towards the buoy the lifting action of the wings would be lessened and the risk of dragging the mooring thus diminished, but if this be done the risk of damage by a sea would be increased (i.) by the sea sweeping up over the tail and (ii.) by the loss of lifting power which served the boats referred to so well in the bad weather at the Scillies and in Harwich Harbour. Heavy anchors must be stowed where their great weight would not interfere with the proper flying trim of the boat, and then, if used to moor by the tail, complications of handling and securing would be involved.

If heavier anchors are carried, the handling of them becomes a very serious matter in any case, and it is strongly recommended that experiments should be made with a view to developing a self-stowing anchor secured in a lily-shaped hawse pipe as devised to meet other difficulties in H.M. battleships and fitted for the first time in H.M.S. "Dreadnought."

The problems of mooring and of handling anchors are perhaps of themselves sufficient to deserve separate consideration.

There is also one small matter I should like to refer to in regard to the use of drogues. The point of attachment of the towing line must be carried to a

position well ahead of the rudder, or else the rudder would become ineffective. Experience in tugs indicates a central position in the ship as the best for the towing hook, on this account.

I can hardly agree with Squadron Leader Maycock's generalisations as to the cause of the lack of effort in producing successful seaplanes. In my opinion the cause was the absence of demand in the United Kingdom. The presence of a serious demand as in the U.S.A. has resulted in the production of seaplanes of amazing efficiency and endurance, which are well adapted for U.S.A. needs. Such craft do not, however, seem to be the most desirable kind of aircraft for this country. Here a more serviceable commercial machine is required and it seems likely that demand will result in the development of flying boats of increasing sizes. The experiences of the three flying boats safely weathering out a gale at Scilly, and the safe flying off of a flying boat in a very high wind at Harwich is very reassuring and very promising for the future of the large flying boats.

I am most strongly convinced that in the flying boat will be found the type of aircraft of the greatest value to the further development of the bonds of our island Empire whose important sections are separated by such great stretches of ocean, and I trust that this paper and the discussion thereon will be a distinct help in that direction.

Colonel SEMPILL (*communicated*): I think that Squadron Commander Maycock's paper is very valuable in focussing attention on seaplanes generally. His contention that they have not received the attention they deserve, or anything like the same attention that aeroplanes have received, is very true.

The lecturer is very well qualified to put before us the practical aspects to be met with in the utilisation of seaplanes, as he has had a unique experience. I would, however, wish that such cruises as he has described could be undertaken by the Royal Air Force more generally and under more varied conditions, in winter for example, and also over longer distances.

It has long been realised that for seaplanes in particular we must get away from the continual man-handling entailed in putting them into and taking them out of their sheds, and construct machines which will weather satisfactorily for long periods. Many of the problems that are entailed cannot be better discovered than by the undertaking of long flights. No doubt the cruise in question showed up many weaknesses, and such information must be of the greatest value when considering future designs.

I notice that the lecturer has said very little on the vexed question as to the merits of the " rigid box-girder " type of hull such as employed on the F.5 and Short " Cromarty " as compared with the " flexible " type of hull with which the late Lieutenant-Commander Linton Hope was associated and as used on the P.5.

Of course, many serious problems that would be met with when operating in winter did not arise, and I would like to suggest that the experience in this direction gained at active service naval air stations during the war might be supplemented. The problem of supplying hot water (or keeping it hot) to the cooling system when machines are suddenly called on patrol and the question of how the oil is to be kept at a suitable temperature requires careful thought; and there are many such problems.

The need for training crews for these flying boats is obviously, from the lecturer's remarks, very acute, but apparently receives very little attention. Personally, I would like to see cruises undertaken regularly with this end in view, every endeavour being made to insist that such machines should be as self-supporting as possible. There is no reason why with certain types the crews should not live aboard.

I must confess that I can hardly agree with the lecturer when he says the use of a water-rudder does not help manœuvrability and has been practically abandoned, as my personal experience goes to show that if the water-rudder is of the right size and in proper position it is of considerable use in manœuvring in crowded fairways, very particularly with single-engined machines. It is to be hoped that the lecturer's enthusiasm for seaplanes may be transmitted to those in authority.

Lieutenant-Colonel J. L. TRAVERS (*contributed*): The title "Airmanship at Sea" is very comprehensive, and the lecturer has only been able to deal with the subject in a general way in the short time at his disposal.

He seems to have laid too much stress on the difficulties involved in seaplane operation, and too little on the tremendous advantages which may be gained by using seaplanes in the right way.

The outstanding points in this subject are:—

(1) The economics of seaplane operation.
(2) The training and supply of personnel.
(3) The best lines for future seaplane design and development.

Every seaplane pilot of experience will agree with the lecturer on the tremendous possibilities of seaplane development both for civil flying and naval co-operation.

A very great economy can be effected by the use of large flying boats operated from moorings by their own crew.

Sheds, aerodromes, slipways, handling parties and ground organisation can be replaced with buoys, dinghies, and perhaps a floating dock.

In the Chilean Naval Air Service flying boats are operated in this way with very satisfactory results.

An F.2a boat has remained afloat for nine months, being put on the beach for cleaning and painting on one occasion. During this period it was operated entirely with its own crew, who carried out all the cleaning, painting, top overhauls of engines, changing of propellers, wing floats, rudder, etc. In fact, it may be said that even with rather old-fashioned flying boats it is possible to operate them as self-contained units.

If the same crew is always kept on the same boat training is greatly simplified, and it is found that a little competition between the different boats makes everybody keen, and the standard of cleanliness, rapid engine starting, and general efficiency is very high.

The ideal design for a seaplane would be very much more durable than existing types, would possess a longer range, and should be arranged so as to operate as a self-contained unit.

In conclusion, as a result of many years' experience of all types of seaplane under different conditions, I should like to say that we do not know how much we can do even with existing types; we are still learning very slowly the extraordinary possibilities of marine aircraft.

To the Editor of the JOURNAL OF THE ROYAL AËRONAUTICAL SOCIETY.

SIR,

I am afraid I cannot agree with Flight Lieutenant Bryer that it is either desirable or possible for any but the smaller types of seaplane to be fitted with amphibian undercarriages. Very great constructional difficulties are already being met in designing undercarriages for the larger and heavily loaded type of land planes, and if we attempt to add these difficulties to the production of a really seaworthy seaplane, progress is liable to another long set-back just as we are learning to rid the flying boat of the necessity of big shore establishments and gaining for it the "utility and independence comparable with that of land planes."

Flight Lieutenant Bryer states an " amphibian is able to taxi up any suitable beach." I should like to ask him what is a suitable beach up which a flying boat amphibian weighing fifteen tons or more could taxi, even if fitted with a caterpillar undercarriage? Has he ever tried to move a V/400 Handley Page on a sticky aerodrome, let alone a suitable beach?

Slipways are, of course, quite suitable for the small amphibian, but they are not to be found everywhere the flying boat of the future will call at.

I know it is said that a prophet has no honour in his own country, but I should like to suggest that the most economical unit of the future will be the self-contained " moored out " flying boat squadron, and that seaplanes will always lead in the matter of size, and as the size of each increases in weight of military load they (seaplanes) can carry. Amphibians are likely to be a passing phase—a temporary but necessary expedient to give ship planes some form of buoyancy if forced to descend on the sea and possessing more moral than practical effect.

I am very glad to see that Colonel Sempill concurs in the necessity of training crews for flying boats. His experience in Japan of training Japanese naval officers to handle this type of aircraft no doubt has impressed the great need of it upon him. As soon as this fact is realised, and pilots are specially trained for the work, the utility of flying boats will increase and rapid development will follow.

One of the most instructive ways of training crews is undoubtedly on cruises away from the base, and if there are any believers that the knowledge common to all pilots is all that is required they should get permission to go on a cruise and conversion would surely follow. It is a pity a special knowledge is essential as it is a " thorn in the side " of progress, but after all we did not expect a locomotive driver in the early days of submarines to operate their machinery. Some of the most amazing things are done by pilots on cruises, even though they are quite experienced in the methods necessary at the base.

It was the necessity of adequate training which I attempted to make my theme in the lecture, and I am glad Colonel Sempill was able to discover it.

As regards the merits of the Linton Hope and " rigid box girder " types of hull, it is early days to pronounce an opinion, but for seaworthiness, watertightness and durability, the former certainly stands out foremost in the limited experience we have had.

With reference to the question of water and oil heating and quick starting from cold—troubles with which were experienced during the war—I think will all be solved in future types by a small auxiliary engine in the hull, heat being obtained from the exhaust and from generated electricity; or, as an alternative, heat will be supplied by cable from the parent ship.

It was with very great regret that I heard of the death of Lieutenant-Colonel Travers, who sent to you just prior to the accident which caused his death his very valuable views on the subject of my lecture. He was one of the few ardent believers in the future of the flying boat, and, having had a long and intimate experience in their development and use, his opinions carry considerable weight.

He said my paper laid too much stress on the difficulties involved in seaplane operation, which is my only point of disagreement with his remarks. I thought I had made it plain that, generally speaking, seaplanes were no more difficult to operate than land planes. All the difficulties which occur arise from a want of training or knowledge of how to handle them on the water. Conditions on the land aerodrome remain fairly constant, but on the sea they vary from day to day. As soon as the pilot learns the effect of these varying conditions on his seaplane his difficulties disappear. I must crave pardon for stressing this point so unmercifully, but I am convinced that the acquisition of the special knowledge required for handling seaplanes is essential, and that until it is generally recog-

nised the development of the flying boat will not progress at the rate it otherwise might.

I agree most heartily with everything else Lieutenant-Colonel Travers said, particularly his remark that " we do not know how much we can do with existing types." This I believe to be very true. Many has been the time when I should have liked to try a rough " take off " or " alighting " and refused the tempting chance which might have been followed by six months of correspondence explaining how it happened, or possibly a court-martial.

On occasions when you have to, it is extraordinary what can be done when life is everything and money no object.

During the war a friend of mine flew out in a 310 Short seaplane from Plymouth to the Scilly Isles to see me without letting me know he was coming. It had been blowing hard and a high sea was running and was much too rough to land, and when I saw him overhead I told him so by W/T. He decided to return to Plymouth with a wind of thirty knots behind. In switching over petrol tanks he got an air lock and had to land in a tremendous sea near the Seven Stones Light Vessel. The air lock was cleared and the engine started again, and it was a case of either " taking off " or breaking up in the sea. He chose the former and arrived safely to become now a distinguished officer in the Air Force. The day was so rough that the Naval Base thought it useless to send out a vessel to search for him, and we considered it hopeless to attempt to send out a flying boat patrol.

We certainly do not know what our existing types can do!

R. B. MAYCOCK.

PROCEEDINGS

NINTH MEETING, 59TH SESSION

A meeting of the Royal Aeronautical Society was held at the Royal Society of Arts, John Street, Adelphi, London, on Thursday, February 21st, 1924. Colonel A. Ogilvie (Chairman of the Society) presided.

The CHAIRMAN, in opening the proceedings, announced that Air Vice-Marshal Sir W. G. H. Salmond, the member of the Air Council who is responsible for supply and research, had telephoned to say that he had intended to attend the meeting, but would not be able to do so because so many of his staff were suffering from influenza, and he could not get away.

The Chairman then called upon Mr. H. Hamshaw Thomas, M.B.E., M.A., F.G.S., Fellow of Downing College, Cambridge, to read his paper on "Some Features in the Present Position of Aerial Photographic Survey."

SOME FEATURES IN THE PRESENT POSITION OF AERIAL PHOTOGRAPHIC SURVEY

Introduction

When I was invited to deliver this lecture I proposed to deal with some aspects of Aeroplane Photographic Survey in which I have been especially interested, but in view of an event which happened on October 13, 1923, viz., the death of Major J. C. Griffiths in a flying accident at Coventry, I have felt that it is my duty to devote some part of this lecture to a consideration of the contributions made by my late friend to the advance of our knowledge of some of the fundamental features underlying the practice of aerial survey. For more than three years, Griffiths, working under the direction of Prof. B. M. Jones, toiled at certain problems which were by no means easy to attack, which were absolutely of first-rate importance as a basis for certain types of survey work, and which when fully investigated provided results which had nothing spectacular about them, but which have laid a firm foundation for future work. Under conditions which were seldom easy and were frequently most discouraging, he worked unremittingly towards the solution of the problems which he was investigating, and has produced results which are of lasting worth. His untimely death was followed by very little public notice, and though some months have now passed, I should like to be allowed to contribute to the Proceedings of this Society some appreciation of his worth.

I propose therefore in the first place to deal with the work of Major Griffiths in the investigation of the problems and methods of aerial survey, and subsequently to pass on to a subject suggested by one of the jobs which he carried out, viz., the relation of aerial photographic survey to scientific knowledge.

Position of Aerial Survey in 1919

At the conclusion of the war, when Griffiths became interested in aerial survey, the position was as follows. Photographs had been extensively employed in France for the correction and addition of features to maps. The methods employed there were only applicable to country which was already fairly well mapped, photographs being utilised singly, and the position of the camera in space at the time of exposure being determined from points on the photos whose

position on the ground was already known. In other areas more extensive map corrections had been made, but with a less degree of accuracy, either by the use of oblique photographs or by means of series of vertical photographs whose scale and position could be approximately ascertained. On the Palestine front the method of mapping from vertical photographs had been considerably elaborated and a new series of maps had been produced by its means covering over 2,000 square miles of country.

Thus aerial survey had become differentiated into two distinct sections with different objects in view. (*a*) To correct and make more accurate the maps of a country whose main features were already well known. (*b*) To produce a useful map of a country whose features were unknown in any detail but in which only a few points had been fixed by previous ground survey. Such a map would show the shape of the ground and all the principal topographical features with considerable relative accuracy, but the absolute positions in space of some of these features would probably be somewhat incorrect.

The Work of the late Major J. C. Griffiths

At the outbreak of the war Griffiths was a student of Engineering and Geology at the University of Liverpool, and during the course of the hostilities, joined the Flying Service and rose to the rank of Major in command of a Squadron in the R.A.F. in France. He did some photographic work, but nothing of a very systematic nature. On demobilisation he returned to Liverpool to complete his course, but now inspired by the idea of using the aeroplane to carry out the work of surveying for topographical and geological purposes. He very soon got in touch with Colonel Winterbotham and later with myself, and eventually decided, on the completion of his course at Liverpool, to come up to Cambridge as an advanced student to carry on research in aerial surveying in the newly-established aeronautical department of the University.

His ideas from the first were to study the possibility of using aerial methods in the survey of new or undeveloped countries which needed to be opened up on account of their natural resources, and so his early interests centred round the type of work which had been done in Palestine.

One of the fundamental theories underlying the work on this front had been that it is possible for a trained pilot to fly over and photograph a line of country at least five miles long while maintaining an approximately constant height and keeping his machine so level that the plate in the camera would never be tilted through more than three to four degrees. The experience of the officers who compiled the maps from the photographs in Palestine indicated that, with care, tilts of more than three degrees were infrequent, and that tilts of not more than two degrees did not greatly damage the value of the work, but surveyors whose experience was chiefly derived from work in France were very sceptical about the possibility of such a performance. They thought that, in general, the Palestine method would be invalidated by the magnitude of the tilts which, in their experience, occurred when a pilot tried to take vertical photographs.

Before any further thought could be given to the development of a method like that used in Palestine for survey work in times of peace and for civil purposes, it was necessary to ascertain definitely what was the average performance of a trained pilot when flying on a straight course and trying to keep his height constant and his machine level. It was to this problem that Griffiths first addressed himself, having obtained a research grant from the Department of Scientific and Industrial Research.

The Air Ministry had allowed Prof. Jones the use of three machines for carrying out research work from Duxford Aerodrome in connection with the School of Aeronautics, and arrangements were made to make the above problem one of the objects of research. Under the direction of Prof. Jones, Griffiths

worked at this problem for nearly two years, doing most of the experimental work and the reductions of the results, and generally acting as the observer during the flight and manipulating the camera.

There was much to be done, especially in the first year of the work. The machines were not fitted for photographic work, and the camera fittings which were available were of a somewhat primitive character. There was little or no skilled photographic staff at the aerodrome and Griffiths had to personally supervise the development of many of his negatives. Camera failures owing to lack of attention to the adjustment of the camera mechanism were frequent. On one occasion, when much time had been spent on fitting a machine, it was damaged at the conclusion of a trial flight; on another, the engine refused to function and a considerable period of time elapsed before it was ready for use. Also the weather proved a constant source of difficulty and disappointment. At one period it would not have been surprising if Griffiths had given up the work in despair.

However, in the course of time he got over most of his difficulties, the Air Ministry provided new camera fittings which incorporated some of the points most necessary for survey work, and the personnel was strengthened by the addition of an experienced photographic staff.

There is little need for me to describe in detail the results obtained; they have been summarised in a joint communication to the Geographical Society* by Prof. Jones and Major Griffiths, and have been described in detail in the reports issued by the C.U. Aeronautical Department.

In the first series of experiments a machine was flown over a level strip of country in the Fens which was well mapped, a series of photographs taken and the position of points on the plates compared with the positions of the corresponding points on the ordnance survey map. This involved a long series of accurate measurements on the plates, and a great deal of this devolved upon Griffiths. Apart from the published results and the main objects of the work, it was incidentally shown that a method of map compilation from aerial photographs which involved a series of accurate direct measurements from the plates would be a very laborious process which could not be recommended in cases where a large area had to be covered in an economical way. After two years' work and the careful measurements of 170 negatives, it was found that, in a machine flown by a trained pilot with all due precaution, the tilt of the camera seldom exceeded two degrees from the vertical and that the change of height from the mean level of each flight seldom varied more than 100 feet, the probable tilt being one degree and the probable variation of height being 40 feet.

This was the first demonstration of the actual course taken in space by a machine during a flight, and it fully justified the view taken by the survey officers in Palestine as to the performances of a skilled pilot. The importance of this work for the future is that it demonstrates beyond all question that straight and level flying is possible under favourable circumstances within such limits as are required for reasonable accuracy in mapping a large expanse of flat country on a medium scale. It shows that the method of air survey by taking a series of vertical photographs is sound and that it is therefore worth developing. It also shows that such work requires the employment of good and specially trained pilots; and finally that it involves far less labour in the compiling office than any method involving the direct measurement of distances on a photographic plate.

I have no doubt that in the future this method will be extensively developed and employed, and this development will rest on the foundation provided by Griffiths' work.

In the autumn of 1921, after some progress had been made in flights over the Fens, I suggested to Griffiths that he should test his pilots' ability to make

* Geographical Journal, Vol. LXI., p. 419, 1923.

a small photographic survey of an area of ground totally unknown to them by taking photographs along three or four parallel lines. The area chosen was Blakeney Harbour on the coast of Norfolk, where a long stretch of shingle and dune land had recently been acquired by the National Trust and where a certain amount of ground survey had recently been done. I knew also that rapid changes had recently gone on in the topography of the shore line and hoped that we might be able to test the efficiency of aerial survey as a means of charting them.

The work was carried out in October and showed that when a pilot had to think of covering a specified area, his flying tended to be less regular, and, conversely, that when he attended to his flying the courses on which he flew were not parallel, and the area was not completely covered by photographs. I remember that this came as somewhat of a surprise to Griffiths and to the pilot, and I believe that this first suggested the second line of inquiry which was then taken up. This was to find out how to fly over an area of ground so as to cover it with a series of straight parallel strips without losing the accuracy obtained in the Fens.

This research was also carried out jointly with Prof. B. M. Jones, who provided methods derived from his extensive experience in connection with the navigation of bomb-carrying aeroplanes. In this work Griffiths generally acted as observer in the experimental flights, working the camera and making the necessary observations and calculations. It involved the testing of several forms of instruments and indicated the value of an apparatus designed by the R.A.E. called the Gyro-azimuth, and also of the gyroscopic rudder control apparatus (when it functions correctly, which was not always the case).

By the elaboration of a system of procedure, allowing for the wind, and using the instruments above mentioned, or even without the gyro rudder control, it was found possible to take photographs along parallel strips over a distance of from ten to fifteen miles without gaps and without losing accuracy. This goes a long way towards a solution of the second problem of aerial survey by the method of vertical photography. It was found by experience that an area of about 100 square miles could be conveniently covered by a machine in one flight lasting three hours. And incidentally it was demonstrated that in a flat country a very good survey could be made at a rapid rate provided that a certain number of points had been fixed by ground survey at distances of about ten miles apart.

The next proceeding was to test the efficiency of the method by making an experimental survey of an area of country round Cambridge, 225 miles in extent —a square whose sides were fifteen miles long. This area was covered by about two days' flying and proved the value of the preceding work.

In connection with this experimental survey the question of map compilation came into consideration. The method employed during the war in Palestine was somewhat long and laborious, for, on account of the very hilly nature of the ground, many systematic errors in the scale of the photographs were introduced which had to be eliminated. It seemed that with an almost flat country and with accurately-taken photographs it might be possible to devise a much more expeditious and easier method. Prof. Jones and Major Griffiths put in a considerable amount of work on this problem and devised a method which is outlined in the Geographical Journal, which was comparatively rapid and which worked very well. A number of photographs combined into a large picture map of a piece of country is described as a mosaic. The prints of the Cambridge area were eventually made into a mosaic showing the whole of the 225 miles of country, and this was adjusted to fit the positions of four control points which formed a rough square with ten-mile sides. Having completed the work the position of the points shown on its various parts was carefully compared with the position of the corresponding points as shown on the ordnance survey map. And it was found that the maximum error of position was never greater than 130 yards, while the

errors were generally less than 60 yards. This is a surprisingly good result, since in part of the area the ground was 400 feet above its level in other parts. Such an area is negligible for practical purposes in reconnaissance maps, say, on a scale of 1-40,000, and is frequently exceeded by the error produced by the change in the dimensions of the paper when an accurate map is mounted on canvas.

While this work was going on, Major Griffiths was approached by certain individuals who were interested in the survey of a large tract of flat country in the Far East, which possesses timber resources of great economic importance, but in which it was impossible to fix points by ground survey at intervals of ten miles. The question that presented itself was—what sort of accuracy of position could be obtained if the known points were 50 or 100 miles apart?

The Cambridge experiments took the form of what has been termed *navigational control*. The general idea was to take a series of strips of photographs at exactly equal intervals along exactly parallel courses of from 50 to 100 miles in length. The starting points of these strips would be known from previous work well checked by ground survey, and as far as possible the strips would end on country which contained a sufficient number of points fixed by reference to ground survey. This series of parallel strips would then be joined by a second series running in a direction at right angles so that the whole area would be divided up into a series of primary squares each with sides of approximately ten miles. By a distribution of errors, it seemed probable that the positions of the corners of each of these squares could be fixed to within between a quarter and half a mile of their actual positions when the ground control points were as far as fifty miles apart.

This work was not completely finished when Major Griffiths left Cambridge to take up his work at Coventry, but much progress had been made and Prof. Jones hopes to complete the work and publish an account of it in the near future. For all practical purposes the degree of accuracy obtainable seems to be sufficient to make this a valuable method in forest or bush country where a primary survey is needed.

The position of the sides or corners of the squares having been obtained in the manner indicated above, the detail in the centre of the squares could be readily filled in either by a mosaic of vertical photographs or in cases where little detail was required by the information supplied by oblique photographs. So long as we have a good method of locating their position and direction, oblique photographs may be of great value in such work.

In the course of the above work Griffiths had materially assisted in developing a scheme of aerial survey applicable especially to large unexplored tracts of flat country. While possessing the same general characters that had been used in war surveys, it differed in several important respects, viz., that the probable error at each stage was known, the special precautions needed to secure accuracy had been studied, and the instruments which might facilitate the work had been tested. Aerial survey based on vertical photographs was previously empirical; it had now become a systematised science. It is for that reason that I venture to think that the work accomplished has in reality a far greater value than might at first appear, and I am in a position to make this observation owing to my experience in the earliest air surveys on a large scale.

I must again point out that while much of Cambridge work applies only to flat or comparatively flat countries, and is inapplicable to regions with high mountains, nevertheless it contains many elements which will be of value in the development of methods of survey in such districts. We in England can do little in the investigation of the problems of air survey among mountains, where vertical photographs can only be of local application, but as far as we have had opportunities for research, I believe they have been employed usefully.

Aerial Survey and Our Knowledge of the Surface of the Earth

I have indicated above some features in the development of the methods of aerial survey for use in flat countries through the agency of vertical photographs, but I do not wish it to be thought that this is the only method of work yet elaborated and that I do not appreciate the value of the methods based on the taking of oblique photographs. I should like to mention that I was one of the first officers to investigate the possibility of mapping from oblique photographs on the British front during the Great War, and as early as March, 1917, I worked out a scheme by which detail seen on oblique photographs could be transferred to a map by the use of a transparent grid marked with perspective lines at known distances apart. This method was, however, found to be inapplicable to the featureless country in which we were then working.

Both methods are being used in practice in Canada where aerial survey, fostered by Dr. E. Deville, Director-General of Surveys, seems to be in a flourishing condition, though still in the experimental stage. In the report on aerial photographic operations for 1922, published by the Dominion of Canada Air Board last year,* the Survey Department contributes an appendix, from which I may quote the opening sentence :—

> "The use of aerial photographs in making topographic maps is a subject of great interest and much investigation throughout the world; to the Dominion of Canada, where such large areas of unmapped country exist, the development of this science is of vital importance."

I do not, however, propose to pursue further the discussion of the methods of aerial survey which have been recently discussed in a very able manner by Lieutenant-Colonel Macleod† in a paper at the Surveyors' Institution. I should like to discuss the question of the design of aeroplanes for survey work, which is of great importance to the future of aerial surveying, but I have not the necessary qualifications for such a task. I propose, however, to consider a question upon which little has yet been written, viz., the nature of the information which may be obtained from an aerial photographic survey.

Many of us recognise that air survey is not likely to be of much use in highly civilised and populated countries such as Europe, and have turned our thoughts towards those vast tracts of the Empire which have as yet been little mapped and developed, but in which homes must be found in the future for many of our race. In such country the work of the surveyors is totally different from the type of work done by surveyors in England. Their task is not the fixation of geographical points or of boundaries with the greatest possible precision, but rather the approximate delineation of great bodies of land and water, the location of important forest areas, of mining claims or of settlers' farms in unknown and unmapped country.

I think it may reasonably be said that as civilisation and the utilisation of the earth's surface by man proceeds, so a more detailed knowledge of the earth's surface becomes necessary. In former years, maps showing the general features of the earth, such as the main divisions between land and water and the principal mountain ranges, were quite sufficient for man's needs. Then in civilised regions more detailed maps on a scale of about 1in. to the mile were needed, in which greater detail was shown. But as time passes we need to know more and more detail about our countries, especially as they are opened up by communications, as cultivation, irrigation, mining and forestry operations are commenced upon them. Thus the ideal survey is the one which provides the greatest possible amount of information, obtained with accuracy and despatch.

Within the period of the Great War the same principle was illustrated in a

* Dominion of Canada. Report of the Air Board for 1922. Ottawa, 1923.
† Transactions of the Surveyors' Institution, Vol. LVI., p. 25, 1923.

marked way. The wealth of detail required for the operations in its concluding stages was infinitely greater than what was deemed necessary during the first year. Even in a campaign like that fought in Palestine, the exact knowledge of the contours of the country at every point along certain roads became of vital importance to the plan of operations, instead of a general knowledge of the direction in which those roads ran.

Aerial survey by vertical photographs approaches the ideal survey at least in one point—it does or can provide the greatest amount of detail about the surface of the ground. The amount of detail is far more than it is ever humanly possible to obtain by a ground survey where any large area has to be covered. It may be possible to see on the photographs taken from a height of 10,000 feet objects on the ground as small as 2ft. across, if they project slightly and cast a shadow. This knowledge of surface detail may in places be of little importance, but in other places may have very great value. Its value may be estimated from two points of view—firstly as increasing our scientific knowledge of the earth, and secondly as having an economic importance in connection with the development of communications, of irrigation and water supply, of agriculture, of forestry and of mining operations. As man pushes out further and further into uninhabited country he needs surveys of the country, and if he can get a primary survey of topographic position, together with all the detailed information necessary for development, much labour will be saved. The British Empire at the present time contains many regions which are waiting for an aerial survey. To quote once more from the Report of Canadian Survey :—

> " The settled part of Canada, of which more or less imperfect maps are available, is confined to a fringe or belt along the southern boundary. The northern part, of immense extent, is very little known. Roads do not exist, the only means of communication being by dog-train in winter and by the lakes and rivers in summer. Traverses along the waterways furnish the basis for such maps as we have. In the best of these traverses, the angles are measured with a theodolite and the distances by stadia or with a range finder. The surveyor completes his plan by sketching such details as he can see from the level of the water; what is beyond the shores or the islands is necessarily omitted." *

Such a survey is no doubt useful as a preliminary reconnaissance, but if any development is to be done the country will probably have to be again surveyed for the purpose. Such work may be long and difficult, and its difficulty may hinder the progress of development for many years. Everyone who has had any experience of finding a way through forest regions without tracks knows how difficult it may be, and yet at the same time there may be natural roads through at least part of the forest zone if they could only be located. An aerial survey in a densely-wooded area presents no more difficulty than a survey over an open area. It may be carried on at the rate mentioned above provided that landing grounds can be found in the vicinity, and in many places landing can be effected for seaplanes on lakes or rivers. Such a survey shows at once where are the natural roads through the forest or at least which are the shortest routes through. It is thus a most important preliminary to the construction of roads or railways.

Similarly, in hilly districts aerial survey, by reason of the complete and rich record of topographic detail, will often show the engineer the best routes along which communications may be built I came across an example of this in North Central Palestine. The plains of Central Syria are divided from Palestine proper by a stretch of very hilly country stretching between Hermon and the sea. At no place are the hills very high, but there no road has ever been made through this country to link up the more prosperous communities to the north and south;

* *Ibid.*, p. 58.

communications involve a very considerable detour to the east or to the west. And yet through this region there exists a natural route difficult to locate on the surface of the ground, but obviously the best means of traversing the hills. This is a dry river valley which once led the drainage of Central Syria into the Jordan Valley. It is not shown on the map prepared by Conder and Kitchener, but was evidently discovered during the war when the making of a road along it was commenced. It was well seen on aerial photographs.

Aerial survey shows every detail in the drainage system of an area, and may thus be of great use in connection with water supply, the sighting of reservoirs, and irrigation. In Canada in 1922 much work was done for this purpose.

> "For the Reclamation Service, Department of the Interior, a large programme of aerial photography was carried out over the streams rising in the eastern slopes of the Rocky Mountains. . . . Photographic reconnaissance for the purpose of locating reservoir sites on several of the streams in this district and continuous oblique photographs of others were undertaken. A complete photographic record of the courses of the more important streams in this district has now been obtained. This cannot but be of great value to the Reclamation Service in its work of preparing plans for the conservation of water in this district and schemes for irrigation." *

Aerial survey is then likely to be of much use in the development of a country.

But I think that we are entitled to look at the matter from rather a different standpoint. I have been so bold as to say that aerial survey is the best form of primary survey because it gives the fullest information about the ground, and this information may have great value to the scientist, besides being of more or less immediate practical application. In these days there is scarcely any need for me to defend the thesis that the advancement of pure science eventually leads to the benefit of the community, and many of the scientific studies furthered by aerial survey are of obvious practical application.

Aerial survey has contributions to make to the science of botany with its more practical sides of agriculture and forestry; to geology with its obvious application to mining and other problems; to archæology with its general appeal to the human mind; and, of course, to the all-embracing science of geography. Let me endeavour to point out a few of the points in this connection which have come to my notice.

Botany.—A most important feature of the earth's surface is provided by the vegetation which covers it. The study of this vegetation and its distribution, the causes which underlie the occurrence of certain types of plant commodities in one spot and the growth of similar or dissimilar vegetation in another locality, form the subject of much investigation by botanists to-day. It may be that some of the plants in the native vegetation have an ultimate economic value, and it may be that the ground occupied by certain types of native vegetation may be readily cultivated or utilised by man, or it may be that the vegetation is a factor which is influencing the shape and extent of topographical features such as coast lines. But in other cases the study of plant distribution may have no immediate practical application and serves only to add to our knowledge of the workings of nature.

It can be readily understood that aerial survey forms a ready means of mapping the extent and distribution of forest, but it may come as a surprise to some to know that in many cases it also enables us to ascertain accurately the numbers of certain trees in any area, the size of those trees or at least the relative size; further, that after a little practice we may recognise certain kinds of trees when we see them on the photographs. Again, aerial survey records the exact extent

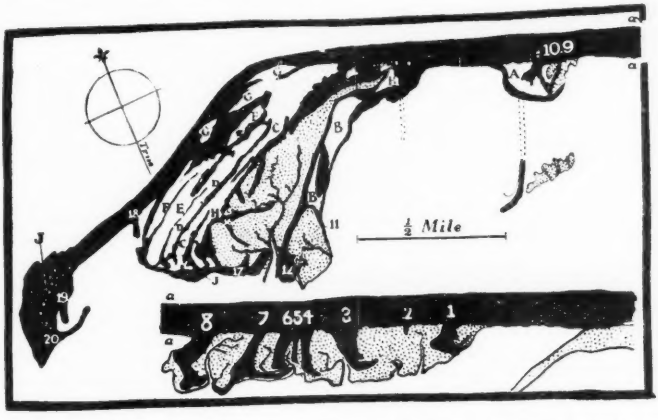
* *Ibid.*, p. 38.

of areas in the forests which have been burned or cut down, and of others in which young timber is again growing up.

Mr. D. R. Cameron, of the Dominion of Canada Forestry Branch, writes :—* "Forest surveys involve the proper definition on accurate base maps of forest types, location of timber bodies, areas of young growth or "burns," together with statements of the amount of merchantable timber on the area surveyed. Experiments have demonstrated the strong possibility of carrying on forest surveys in non-mountainous regions more economically and more accurately from the air than can be done on the ground. Certainly a much more valuable and comprehensive survey of general forest conditions can be made from the air than can be obtained with the same expenditure of money on ground work. Particularly valuable is the possibility of accurately locating areas of young growth of valuable species, on which the future forest industries of Canada depend." On a subsequent page he writes :—†". . . this service is making a special study of pine reproduction in Central Ontario. Aerial photography is the most logical method of undertaking this work, because in this way results can be obtained in one season, which by old ground methods would take years to complete. Another special study with tremendous possibilities is the proposed conduct of experimental work and research in making detailed timber estimates by aerial photography."

A forest tree is a big thing, and it is not surprising that in photos of coniferous forests we can often distinguish each individual full-grown tree, but even when the vegetation of the ground is composed of tiny plants, the all-seeing eye of the camera may be able to record their presence.

I have already referred to the survey of Blakeney Harbour in Norfolk, and I may here mention some points of interest which were derived from the study of the photographs taken at this spot.



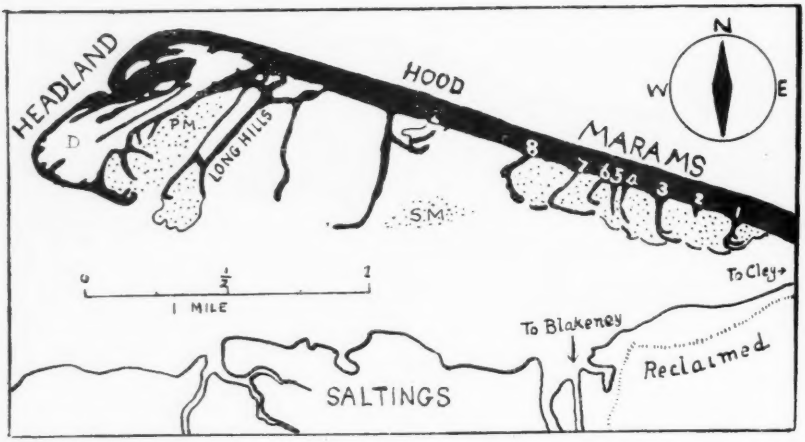
Sketch map of Blakeney Harbour in 1913, *showing the rounded form of the headland. Made from ground survey.* (*From Oliver J. of E.*, 1913.)

The ground surveyed was to a considerable extent covered with the natural vegetation of maritime areas. It included sand dunes with their tufted grasses; much of the area was salt marsh with a variety of plants, varying from tangled masses of the sea-weed *Pelvetia*; tracts covered with the sea lavender; sward more or less carpeted with grasses, to a good deal of bare mud without any

* *Ibid.*, p. 71. † *Ibid.*, p. 74.

plants. The great shingle spit bears the important bushy *Suaeda fruticosa*, which helps to stabilise it, with other occasional plants. We found that our aerial survey provided quite a good map of all this vegetation at the same time as it gave the complicated topographical detail. After a short time on the ground with the photographs one could soon recognise how each type of vegetation was depicted, and the relation of several of the vegetation types to the topography was at once shown.

For example, we can see how the incipient dunes are being colonised by the marram grass, any tuft over 2ft. across being visible on the prints; the grass on the younger dunes is still in isolated tufts, but on the older dunes marram and other grasses have grown together, forming a more or less continuous covering and anchoring the blowing sand. The shingle-binding *Suaeda* is clearly seen



Sketch map of Blakeney Harbour in 1921, *made from aerial photographs. Note the new shingle spit (J) which has been formed since* 1913. *The shingle is indicated by solid black. The salt marshes dotted.*
(From Salisbury Ann. Bot., 1922.)

as a line of darker dots, and tracing it along the bank we come to an area in which it has died out. Such an area will be most liable to the attack of the waves in a storm, and, in fact, after the first survey was made a very high tide and rough weather broke through the beach at this point, destroyed the concrete sea wall and flooded the pastures behind it. We see the early stages in the colonisation of bare mud by vegetation, a process which will probably end in the replacement of mud flats by a luxurious sward.

We shall hear more of the scientific results of the survey from the pen of Prof. F. W. Oliver, F.R.S., who in a recently published report to the National Trust states " I have no hesitation in saying that a notable contribution has been made to the knowledge of the topography of the Point and that air photography promises to become an adjunct of value, whether applied to general cartographic purposes or to vegetation mapping."

The topographical side of this work merits more attention than I am here able to devote to it. Blakeney Point is one of those areas where the coast line is undergoing rapid changes, so rapid in fact that the charts made by ordinary methods soon become out of date. The changes which took place between 1913 and 1921, especially the building of a new spit nearly a mile in length, are shown

by the two maps reproduced—one from a ground survey, the other from an air survey. The new Point was photographed three times in 1921—in May, October and December—and each time appreciable changes were noticed, especially in the reflexed part of the hook of the new Point, which moved nearly 100 yards between October and December. The importance of a rapid means of survey of the kind which can be carried out in a few hours is obvious, for though the sea-going traffic from the village of Blakeney is not large, there may be many other parts of the world in which similar changes are going on which are vital to navigation and sea-borne commerce.

In this connection I may point out that the approach to one of our greatest ports is at present in need of a survey which can only be done from the air without very great labour.

Part of Blakeney Point, Norfolk, showing the new spit on the left, sand dunes in the centre and salt marsh on the right.

Southampton Water and the neighbouring shores are being invaded by a salt marsh grass *Spartina Townsendi*, which was unknown till 1870. Appearing at first in a few clumps, it has spread with astonishing rapidity, and now covers great areas which were formerly mud flats exposed at low water. It has spread into Poole Harbour, where it covers large areas, and eastward as far as Rye, while across the Channel it is establishing itself in France. While I do not anticipate that this rapid growth of vegetation will influence greatly the main Channel to Southampton in the near future, it may ultimately do so, and it considerably alters the appearance of the banks. An annual aerial survey which could be put into the hands of those who are studying such tidal lands would be of great scientific interest and perhaps of ultimate commercial importance, since nobody really knows what will be the results of this remarkable growth of the Spartina grass.

Geology.—The scientific study of the structure of the earth's crust will be greatly assisted by the execution of aerial photographic surveys. The geologist has two sides to his work—one the study of the surface features and the recognition of the causes which have brought about the present topography, and secondly the study of the underlying rocks and their contents. This scientific study has a practical outcome in the investigation of water supply and of the distribution of deposits of coal, oil, ores and other mineral substances.

The value of the air picture in the study of surface features is obvious. Not only does it display the main features of the ground, but also the smaller details

such as could seldom be shown even on a good topographical map. The investigation of these features on the ground would require a very laborious and long-continued survey, which in many parts of the world would be almost out of the question on account of the difficulty of maintaining an expedition in the field for a sufficiently long period.

In this connection I may mention that the aerial survey of Palestine has provided data for the scientific exploration of many of the complicated and difficult points in the surface features of this country. As an example we may notice the geology of the Jordan Valley. It would appear that the present Dead Sea is the last remnant of a very much larger sheet of water which once spread upwards and was connected with the Sea of Galilee. The floor of the Valley is now filled with flat beds of calcareous mud laid down on the bed of this great inland sea. What has been the cause of the great diminution of the area of the water?

The aerial survey shows that the drainage system of the large part of Central Syria with its high mountains once flowed into the Jordan Valley, but the channel along which this drainage passed in bygone times is now empty. The water which once poured down through it in a great stream has been captured by a smaller river and is now led directly to the coast, and so the water supply of the Jordan has been very greatly diminished and is restricted to streams arising in its own vicinity.

We may pass from this example to consider how aerial survey may help the progress of knowledge as to the structure of the earth, and we must first note that this knowledge depends very largely on geological mapping. A geological map shows the distribution of the outcrops of the various types of rock on the surface, and this, with a knowledge of the dip and the nature of the rock, goes a long way in the elucidation of structure and the explanation of what happens underground. Obviously we cannot at once turn an air survey map into a geological map, but the air survey will very much lighten the work of the geologist and enable him to cover large areas of ground in a more detailed manner. In the first place the photographs will show exactly where outcrops of the underlying rock are to be found, and the geologist can proceed to them without having to spend much time in searching through a large area mostly covered with soil and vegetation. Then in the same way as mentioned in the case of vegetation surveys, the geologist will often be able to map the extent of country occupied by outcrops of a particular kind of rock after a short exploration and comparison of the photographs with the actual rock features in any district. In more exceptional cases, such as in many parts of Palestine, the individual beds of rock in a formation may be recognised in the photographs and render their mapping a much easier matter. In all cases an air survey will greatly facilitate the first investigation of the geology of a country, which is a preliminary to the location of deposits of mineral wealth. This has been recognised by the Canadian Department of Mines and by the United States Department of Mines.

In the investigation of water supply problems, progress will be facilitated not only by the accurate portrayal of the courses of streams and rivers by aerial survey, but also owing to the fact that the position of springs is very readily located by the camera.

Archæology.—I have above touched on the application of aerial survey in two branches of science which have in many respects important practical application, and I should finally mention one further study which has already derived some benefit from air work and will in the future derive more, but which has less bearing on the economic development of a country. The study of archæology has, however, a great fascination for the average civilised man, and it has long been the practice to show in our English ordnance maps features of archæological interest.

There is no need to refer to the interesting discoveries at Stonehenge

resulting from aerial survey, but I should like to mention how in many places at home and abroad an air survey will bring to light features of historical and archæological importance in a striking way. In the case of the remains of ancient buildings, the air photograph may give their ground plan, without a prolonged series of measurements being taken on the ground. In other cases remains of historic or prehistoric buildings are buried under an accumulation of soil and débris, and may escape the notice of the traveller on the ground. In such cases the aerial survey photograph may reveal the presence of these buried structures, for when viewed from above we can quickly recognise any symmetry that may occur in mounds of earth which often cover old sites which, when examined on the ground, appear without order and show little trace of man's handiwork.

One of the most striking examples of this was seen in the vertical photographs of the ancient ninth century city at Samarra in Mesopotamia.* Here the ground plan of large areas could be clearly seen, with the sites of the streets, buildings and houses perfectly outlined. It is hard to believe that these are not distinctly seen on the ground, but yet it is said by those who have been there that the site appears to show in most places nothing but a vast series of shapeless and irregular mounds of earth. This example is provided by the ruins of a comparatively recent city, but it serves to illustrate the general principle. In many parts of the world aerial survey should, if carried out, be of very great help in the study of ancient monuments, cities and civilisations.

One further example may be given. At the present day all the southern part of the Jordan Valley north of the Dead Sea is a very arid and desolate region, with very little cultivation and very few inhabitants. Yet according to the Biblical story it was once a very fertile district, and one wonders what could have given rise to this idea. It was interesting to find as the result of air survey that in some parts of the eastern side of the valley there are remains of an extensive system of irrigation channels arranged in regular lines, which watered the ground with water from the hills of Moab. These channels are shown owing to the fact that they are filled with scrub-like plants which are less regularly arranged and less abundant in the surrounding country and in the flats between the channels. We cannot tell, of course, what is the age of these irrigation systems, but they are probably of considerable antiquity.

There is always a possibility that areas like these which have been cultivated in ancient times might be again opened up and brought under cultivation, and so discoveries of antiquarian interest might become of modern economic importance.

Conclusion

We have seen in the first part of the lecture how progress has been made in the working out of methods of aerial survey on a basis of vertical photographs and how it has become possible to carry out reconnaisssance surveys over great tracts of country with extraordinary rapidity and probably in the end with considerable economy. While in some cases the work will be best done with the help of oblique photographs, in other areas a complete mosaic of vertical photographs may be advantageous. Such photographs will supply a very accurate and detailed source of topographical knowledge.

In the second part of this communication we have seen how at the same time as the topographical information is gained, in many places a great deal of other information can be derived from the photographs, which has at the same time both a scientific and an economic value. Scientific knowledge that adds to man's information about the processes of nature is valuable for that alone, but as we all know, in the course of time pure science contributes to man's welfare and his comfort, even though that knowledge appears to have no immediate practical

* See Beazeley, G. A., " Geographical Journal," Vol. 53, p. 330, 1919.

application. But the knowledge gained from aerial surveys is already having important economic applications. It helps in the work of reclaiming land for agriculture and in showing what areas are the most suitable for the culture of certain crops. It helps in the work of developing water supply and in the utilisation of streams and rivers either for irrigation or for the generation of power. It forms the only known practical method of ascertaining the distribution of forest trees over a large area, of mapping densely-forested regions, of showing the area felled or burned, and of studying the regeneration of such areas. It greatly assists in the work of geological surveying and so facilitates the discovery and development of deposits of coal and valuable minerals.

In all the above-mentioned directions the great utility of aerial survey has already been proved, especially by work in Canada. Aeroplane photographic surveys would be very valuable if they only provided the information on the subjects mentioned in the last paragraph, but when this provision is added to the value of the topographic maps, we are forced to the conclusion that for an undeveloped country rich in natural resources, aerial photography is the pre-eminent method of topographical survey, and considering all the purposes to which it can be put, and the rapidity with which great areas can be traversed, it must in the long run be the most economical method.

We must not forget that even if at first a topographical map is the chief requisite and it is not desired to exploit water systems or to estimate forest reserves in detail, the photographs when taken may be kept for years, and at a much later period may be used for such purposes or assist in the work of a geological or vegetational survey. Unless man is actively engaged in changing the surface of the country, the processes of nature are very slow, and often the passage of half a century or more would not diminish the value of the photographs. So in uninhabited regions a photographic survey might be regarded as something permanent, which could be referred to from time to time as need arose. Its first use might be merely for maps on a small scale, but later in some localities it could be made the basis of a new series of maps on a much larger scale, of forest maps, or of geological maps. At a still later period it may be useful to provide information for the construction of roads or railways, and for the formation of towns or villages. Again, the time might come when water power was needed, and the old photographs might again be studied from this point of view. At the present time it is infrequent that the first survey can be utilised for any or all of these objects, and as each stage arrives in the development of a country a new survey has to be made.

But if we agree upon the value of the aerial method of survey, we may still have some doubts as to its practicability. The Survey of India initiated experiments on lines which I suggested in 1919, and the results* seemed to indicate that the method was liable to partial, if not complete, failure. I judge it probable, perhaps certain, that other failures will occur before the factors necessary for success are realised.

Success will only be achieved if all who are concerned thoroughly appreciate the part which they have to play in the work, the difficulties which may arise, the errors which have to be guarded against. The commonest mistake that is now current is that any skilful pilot can be sent up with a machine to take survey photographs over an area, without previous training or full knowledge of what he has to do and what not to do. But all turns on the abilities of the pilot, and he must have gone through some course of training before he actually starts on a survey. Even if he knows what he has to do, he may, without previous training, find that when he gets into the air he is unable to do what he wishes; while looking for his starting point he loses height, while trying to get on his compass

* Professional Paper No. 19. Survey of India, 1920.

course he gets one wing down, and so on. The remedy for this is not to abandon any system which tests the skill of the pilot, but to train him and his observer thoroughly for the job.

The whole of the procedure must be carefully analysed and it must be arranged exactly so that it becomes a matter of routine. In England, under favourable weather conditions, it would probably be impossible to train a pilot in less than

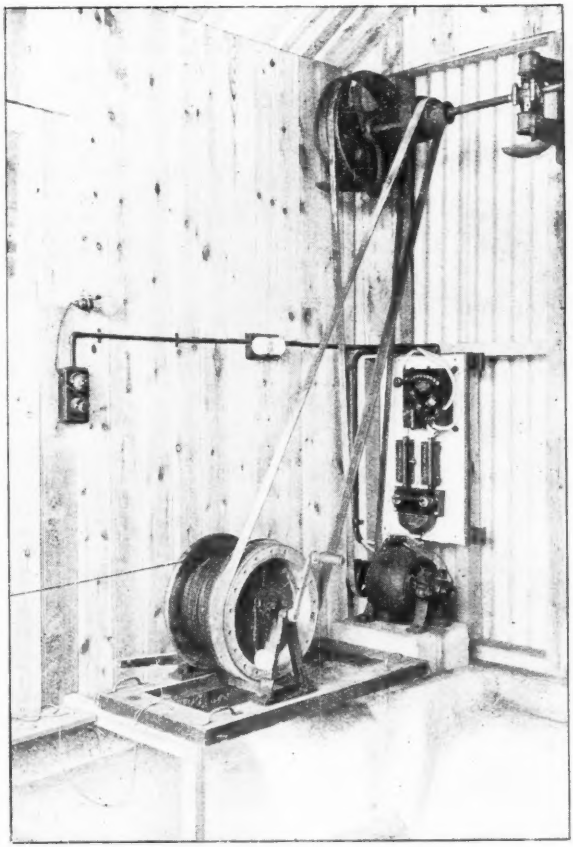


FIG. 1.
Electric-driven winch in the balloon shed at Strawberry Hill.

a month to reach the standard of skill necessary for the commencement of survey work. The observer might probably learn his work in a shorter time. The performances of the pilot must be checked carefully at each stage, and he must be proficient in one stage before passing to the next. Every surveyor needs a more or less long course of training, and the aerial surveyor is no exception to the rule.

But my own experience shows that pilots can be trained to do all that is required of them and indicates that with more practice a good man will even exceed the area indicated as the space covered by a day's work, viz., 100 square miles.

The British Empire presents a great field of operations for air survey. It has vast undeveloped and unmapped territories with great natural resources, which are gradually being utilised as time goes on. The need for maps or better maps is being felt in many quarters, and in many places the difficulties in the way of ground survey are very great.

There may be little or no call for aerial survey in Europe, but if the Dominions require it in areas overseas, England may be requested to provide machines and personnel. Most, if not all, of the work yet accomplished has been done with machines built for another purpose. If British aeronautical engineers wish to help in the work, they may design a very steady machine which may be quite slow but which will climb to 10,000ft.; which will land at a slow speed on small landing grounds or on water. If a cheap and easily transportable machine can be produced

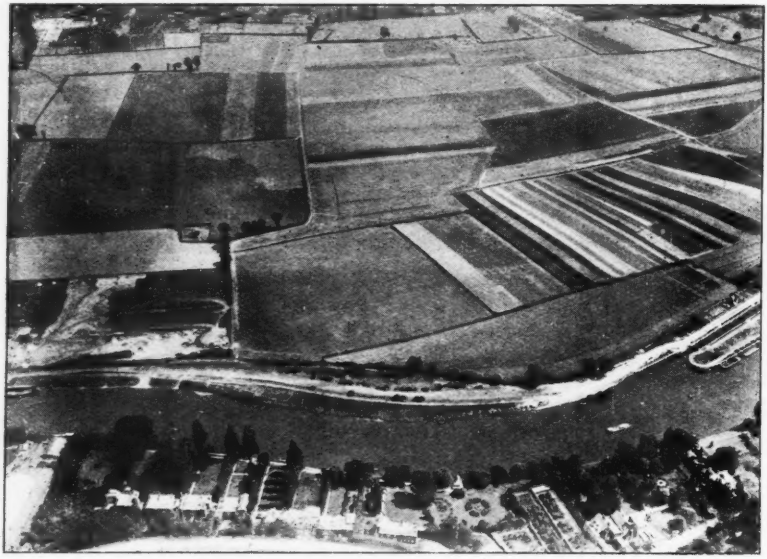


FIG. 2.

View taken in 1906 from the captive balloon of 500 c. ft. capacity let up to 1,500 feet from the winch at Strawberry Hill.

a great impetus will be given to air survey, which in spite of its advantages is bound to be somewhat costly.

Canada has led the way in showing what can be done and how aerial surveys can be utilised, and other colonies are following her and seeking for information as to methods and apparatus. England is probably the least suitable part of the Empire for the practice of air survey and even for experiment, but I think that she has played an honourable part in the development of the science still in its infancy, and I trust that in connection with this development the name of Major J. C. Griffiths will always be remembered.

NOTE.—In sending the photos taken from his captive balloon in 1906 and 1907, Mr. Griffith Brewer says:—

"The difference between aerial photos taken from an aeroplane and those from a captive balloon rests merely in the choice of the platform. To secure good

photos of the ground from a camera carried on a captive balloon, the operator must be able to travel on the land or water directly below, or in the neighbourhood of the country to be surveyed. Photos taken from an aeroplane do not suffer from this restriction and are therefore more useful in war, but on the other hand the position and altitude for the camera may be chosen with greater accuracy from a captive balloon than from an aeroplane, and for aerial survey, when access to the ground below is possible, a small kite balloon held stationary on its cable is the preferable platform."

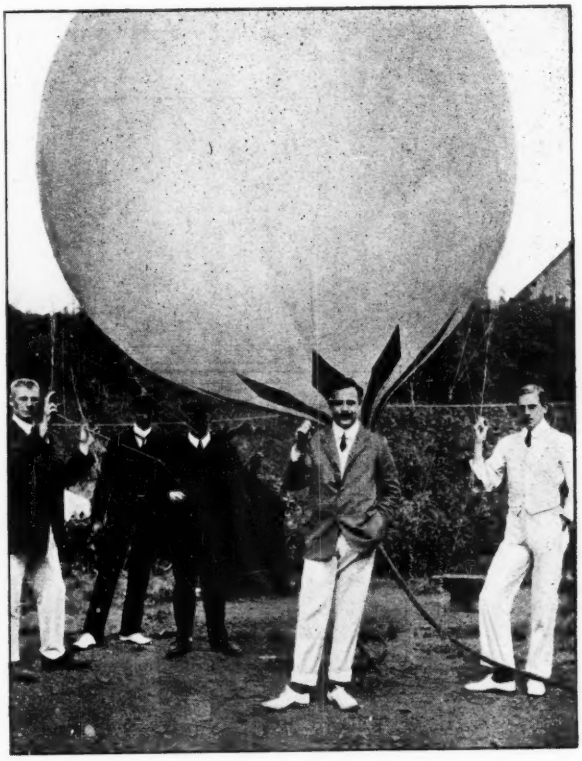


FIG. 3.

Left to right—Mr. Fentiman, Mr. Eric Clift, Mr. Frank H. Butler, Commander H. Perrin (Sec., R. Aero Club) and Mr. Barr assisting in the inflation of the captive balloon at Netley, Southampton Water (1907).

DISCUSSION

Colonel WINTERBOTHAM (Chairman of the Air Survey Committee), who opened the discussion, at the invitation of the Chairman, said he did not want to give the views of official bodies, but would like to give his own personal views on the questions raised in this admirable paper. After expressing the thanks of the meeting to Mr. Hamshaw Thomas for his very admirable lecture and slides, he said we were all accustomed to regard the English language as one which was so wealthy that in it one could always find a word with the shade of meaning which

was appropriate to the subject in hand, but there was a bare spot when we came to matters of survey. We wanted several more terms in order to define exactly what we meant. There were perhaps three or four times as many people in England who were called surveyors as were actually dealing with the fascinating question of topography. For the most part, British surveyors were busy on other matters which were of equal importance to the development of the nation. In the same way we lacked some sort of definition in talking of aerial survey. The matter really divided itself into two headings. There was the question of aerial photography for map-making, and the question of aerial photography for geographical research. The two things were not at all the same, and it became more obvious as time went on that aerial photography had perhaps no rivals at all in the matter of dealing with the geographical research which was so important from the scientific aspect. It had rivals, however, when we came to the question

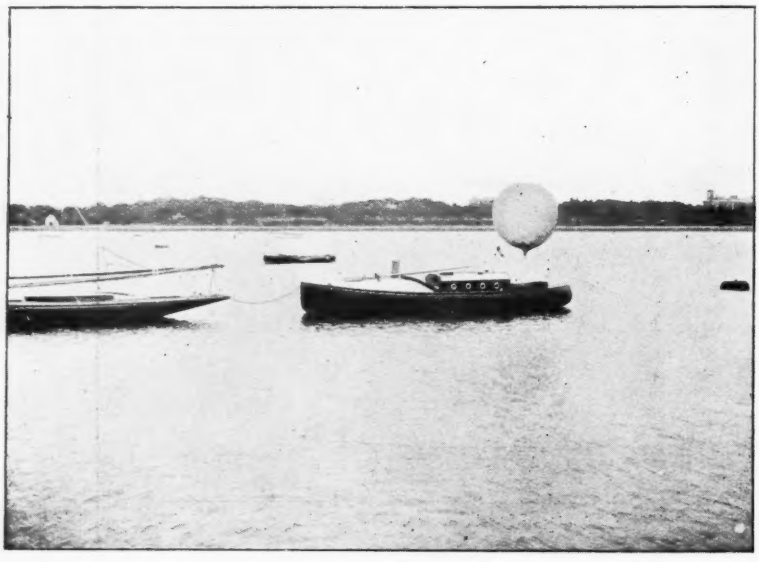


FIG. 4.

Launch in Southampton Water with winch on board and balloon ready to proceed to object to be photographed.

of map-making. Mr. Thomas had said how archæologists, botanists and geologists, water conservancy and coast erosion boards might confidently expect help which they could not get from anywhere else. Colonel Winterbotham referred to a lecture given by Mr. Crawford, the Ordnance Survey Archæologist. From air photographs he had shown us the type of field division which was current in England in times before the advent of our Anglo-Saxon forefathers. It was to him astonishing that traces of that pre-Saxon agriculture should still be visible. He had noticed in a paper a few days ago that in Germany the fishery boards were looking for mussel beds, under water, and locating them, from air photographs. It was in the direction of geographical research that Canada was giving us so admirable and so enlightening an example. It was not in maps. However, he was a convinced map maker, and was bound to come back to that question. On the whole, he did not agree with Mr. Thomas in drawing a sharp distinction between the work in Palestine and that in France. In both cases the initial

trigonometrical survey was given by a former survey. In both cases the contouring, at any rate precise contouring, was not done from the air photographs. Both in Palestine and in France they were able to correct contours and to add to them locally, but, in a broad sense, it could be said that it was not done from air photographs. It was unfortunate for the development of air survey that in this question of map-making the ground surveyor had provided methods which, from long experience, had become both cheap and reliable, and it was against that competition that air photography had so far failed to make its way. That was no reason at all, however, why one should feel profoundly distressed, or say that our photographs would not so be used. He thought they would, but we had to remember that we were up against people who knew their job, and if we wished to

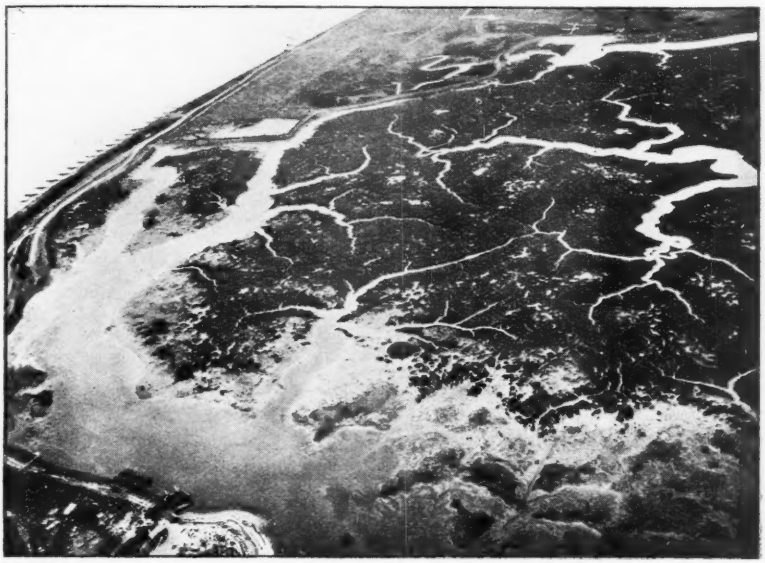


FIG. 5.

Mud flats at Calshot as they were in 1907, photographed from the balloon 900 ft. above the launch.

push aerial photography for map-making we had to walk warily and to study the question of £ s. d. It must be remembered that we have no war conditions now. In war the taxpayer was only too glad to give us what we wanted in the way of money if we were getting on with the job of beating the other fellow, but in peace the conditions were different, and the question of expense was important. Why could not we get down to making aerial photography economically a rival in map-making? At present we failed partly because we were not doing enough by aerial photography. All systems of our photo topography failed to touch the surveyor's first task—his trigonometrical work. In Mr. Hamshaw Thomas's system the photographs were then taken and plotted from, and then the ground surveyor had again to go out on the ground for contouring; so that air photography was really taking something like one-third of the work of the surveyor off his hands. If that was to be the case, we must do it at a cost of somewhere about 7/- or 8/- per square mile, or else we were not economic rivals. That was why we had heard so much of the question since the war, and yet practically every-

where surveying from air photographs had been shattered on this economic question. But we should eventually overcome our difficulties. In order to do so, however, we must devote a good deal of time to research, and that research had to be directed to five points. The first, and the most important, was the design of a satisfactory aeroplane. Every word that Mr. Thomas had said in that connection was sound. The next question was that of the design of the photographic apparatus best suited for the job. Enormous strides had been made by the Air Ministry since the war, and the efficiency of the photographic outfit had increased 300 or 400 per cent. The third point was the training and the methods of the pilot—the question of navigational control—and it was in that branch of research that we were so very much indebted to the work of the Cambridge

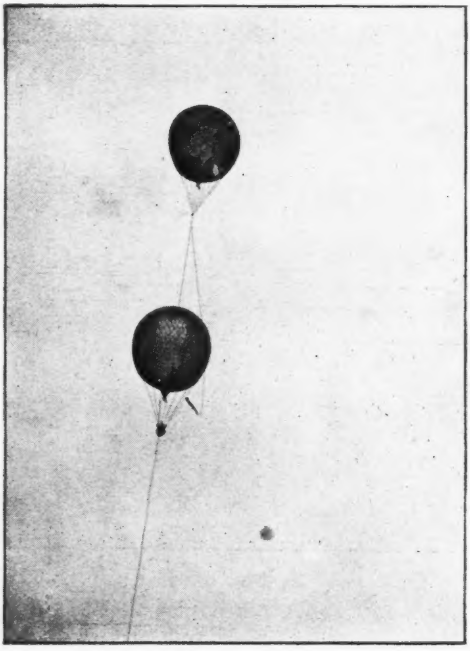


FIG. 6.

When hydrogen was not available and heavy coal gas had to be used, two balloons each of 500 c. ft. were employed to lift the camera.

school, and in particular, perhaps, to Major Griffiths. The fourth point was the question of plotting from air photographs. There were all sorts of ways of plotting, and almost every day somebody rolled up with a new method. There were a thousand and one ways of plotting from air photographs, and it was feasible to plot from them any survey we liked in any part of the earth. But we had to find the most economical one, and that had probably to be a mechanical and automatic one. Lastly, we had to consider the question of contours. It might be cheaper always to send the surveyor out on the ground and contour after the aeroplane had finished, but in that case we must recognise that we had to do our photography for very much less money than we spend on it at present. It might be that in the future we should be able to contour so rapidly from the air photo-

graphs themselves that we could do away with the man on the ground. In mentioning the names of one or two investigators connected with this matter, Colonel Winterbotham said that Major McLeod, Mr. McCaw and Major King, of the Air Survey Committee, had contributed much to its success, and in the work of training, and in connection with navigational methods, the Cambridge work had been extremely valuable. In a tribute to the late Major Griffiths, Colonel Winterbotham said that, so keen and so interested was he in the line that he had mapped

Vertical photograph showing the geological structure of the ground in the hilly region of Central Sinai.

out for himself to follow, that on one occasion, in 1922, he came upon a subject to which he thought he might find the answer for the Ordnance Survey. It was about 2 p.m., and he jumped on to a motor cycle, forgetting even his cap, and rolled up at Southampton to get the answer to this point the same afternoon. We all deeply deplored his very unfortunate end. Referring to Mr. Thomas's remarks as to the extraordinary volume of detailed information obtained from an

air photograph, and the fact that he had instanced that as one of its great values for map-making, Colonel Winterbotham said it was of great value in geographical research, but not so much in map-making. On a map there was no room for an enormous mass of detail. An artist, when painting, shrouded a lot of his work in atmosphere, and gave the eye just what the eye wanted. It did not want a lot of detail. In the same way, if one took one's wife to a photographer, when the photograph was finished one did not wish to observe on her face those wrinkles for which one was perhaps one's self responsible. We had them obliterated.

General Sir W. S. BRANCKER said that only about a month previously he was in Canada, hearing from the people on the spot what they thought of aerial survey. There was no doubt that the Canadian Government had come to the conclusion that it was distinctly the cheapest way of going on with the survey, already started, over the vast area of unknown territory in Saskatchewan, Manitoba and Alberta. He did not know exactly what Colonel Winterbotham meant by "map-making," but they were certainly working very hard on maps in Canada. He might call it filling in and correcting. They had told him (General Brancker) that the maps of Canada as they stand to-day only show about half the amount of water which actually exists, and that most of the water shown on the maps to-day is shown quite inaccurately. Generally speaking, their method was to use oblique photographs. They selected an area, of which they wanted to make maps. They selected two points, which were already located by survey some time beforehand, and worked between them. They flew, generally speaking, on a direct course, and at every three to five miles they took three oblique photographs—one straight ahead, one half-right, and one half-left. Those were brought in, and the ground work was then undertaken. With the aid of these photographs, a survey party went out in canoes, and made a traverse along the route followed by the aeroplane. In this traverse certain definite spots were located by survey. Then, by some means which he was not sufficient of an expert to understand, they produced a celluloid grid, and by applying this to each photograph—it fitted exactly to scale—they could absolutely fill in on the map the shape of the ground. They said that it would save untold time and a great deal of money, and, of course, it would at the same time give a vast amount of information concerning the forests themselves; taking it all round, this method of aerial survey would probably mean millions sterling saved before they finished with the work. He had found tremendous enthusiasm for aerial survey everywhere in Canada, and, as the result of attending two meetings—one of the Lumbermen's Association and one of the Engineering Association—they had given him two specifications of the types of aircraft they considered necessary for aerial work in Canada. That included work, not only in survey, but also for forest protection and control—fire-fighting—and he had brought the specifications home and hoped to get the Research Department of the Air Ministry on to them, to see if we could produce experimental machines on the basis of the experience gained to meet these demands. In both specifications they asked for "pushers," and they wanted particularly water-borne machines. They asked for an air-cooled engine because of the intense cold experienced in some parts of the year, as well as ability to land both on water and ice, and ability to land at low speeds. The actual performances required were very easily fulfilled, but what they underlined again and again and again was economy, both in first cost and operating cost. They considered that with a cheap machine, both in running costs and in purchase price, they would be able to prove that their air survey was much the cheapest way of carrying out their further mapping work. Not very much vertical work had been done in Canada, but it was being used for filling in and correcting existing maps dealing with mining claims and allocating them exactly—a thing they had had great difficulty in doing before. Before aviation came to the rescue, when a man came along and said he had some land in a certain place, they could not tell within five miles exactly where it was located. By means of aerial photography,

however, they were really getting these claims accurately registered. Going on to America, he had found rather the reverse. There, again, the value of air survey was beginning to make itself felt, but they had done very little oblique photography, and a great deal of vertical. Most of the vertical had been applied to correcting existing maps, most of which were out of date, and was also used by commercial companies for deciding the exact alignment of new power lines, pipe lines, railways, and so on. Also, the Americans had done a complete vertical mosaic of New York for the New York municipality, and he had never seen anything to touch it anywhere. It was being used for thinking out improvements in street communications, and so on. The opinion in Canada was that America had got a bit ahead of us in the production of a practical camera. They had the Fairchild camera, which was a film camera with a very sensitive film; being very sensitive, these films only lasted a short time, and had to be very carefully stored and handled. It also had a shutter very like the old Kodak shutter, instead of the arrangement which one pulled across the lens, and which had certain serious drawbacks. The results they were getting from that camera in Canada were most remarkable, and they were certainly some of the best photographs he had ever seen anywhere. The Fairchild people claimed that they were developing a four-lens camera combined with a gyroscope, and said that when they had got that they would be able to produce contours accurately by some means of locating the centre point of each photograph and working with a 75 per cent. overlap. It would give exposures between 1 in 10 secs. and 1 in 90 secs. All he could say was that it was necessary to go to Canada, and hear the people on the spot, in order to realise what they felt about it. His own feeling was that we should benefit by their experience as much as possible, work in with them and get some of our survey experts over there, to see what they were doing, and from their experience we could help the rest of the Empire in this most important branch of civil aviation.

Professor MELVILL JONES thanked Mr. Thomas very heartily for having devoted part of his lecture to an appreciation of the late Major Griffiths. Major Griffiths and himself had worked together on this surveying problem for about three years, and in that time he (Prof. Jones) had developed an extraordinarily high opinion of Major Griffiths' abilities, whilst at the same time they became very great friends. It was particularly distressing when a man of his ability—which was quite exceptional—was killed at the beginning of his career, before he had really had time to do much of the work that he would have been able to do. Major Griffiths did extremely well at Liverpool University in engineering and geology, and then he had obtained an immense amount of flying experience during the war. (He rose to be a Squadron Leader at the age of 22.) He was the kind of man who knew absolutely his own mind; he decided that his life's work was going to be aerial survey, despite the fact that there was at that time no employment to be obtained in this sphere of action. Professor Jones said he had never had to work with a man of such "catastrophic" energy; it was something tremendous. A man like that, absolutely undaunted, as he was, by either danger or difficulties, and with tremendous energy and high scientific attainment, simply could not help making a mark in the world. He was just about to begin doing that when he was killed.

Referring to Mr. Thomas's paper, Professor Jones said that Mr. Thomas had given, as well as could be given in the short time at his disposal, an account of the work that had been done at Cambridge. What he had not mentioned, however, was that he (Mr. Thomas) had himself originated that work. Mr. Thomas, in the first place, suggested the outlines of the scheme that was eventually adopted, and, with the help of Colonel Winterbotham, discovered Major Griffiths and sent him along to help. Practically all the predictions made by Mr. Thomas when they had started the work had been fulfilled.

There was one important point which had come out of the work, and which

he wanted to emphasise—it showed that comparatively high accuracy could be obtained with surprisingly simple methods, but it also showed that one could not get any accuracy at all unless one went for the job with properly-trained men, properly-chosen aeroplanes, properly-chosen equipment, and, above all, a properly-thought-out scheme. Unless one had some definite scheme which was well thought out, and unless one trained the men in it before starting work, one could expect no accuracy at all. The one thing he was afraid of, and had been afraid of for some time, was that in the British Empire—not in Canada, apparently, because, as Sir Sefton Brancker had said, Canada had already caught fire in this connection, and nothing would stop it—in other parts of the British Empire than Canada, we might try to be too hasty. It was extremely important that too hasty attempts should not be made to use aerial surveying in economic competition with other surveying methods until we were quite sure that we were on the right system, and until we had properly trained the men; to obtain all these things would take money and time. He should imagine that, now Canada had started, by getting experience from there we should be able to get along in the other Colonies as well. He was extremely interested to hear of the method of working with obliques from long, straight flights. A very similar method was the one that Major Griffiths and himself were starting on just before Major Griffiths was killed. In fact, Major Griffiths had carried out one 100-mile and two 60-mile straight flights in order to try the accuracy of that method, but he had had to leave it for a while, and was killed while he was away. He himself (Prof. Jones) had tried to carry on that method as far as he could in the intervals between other work; he had got a little further, and hoped to be able to publish the results soon, and it seemed to him that along these lines was the way in which the undeveloped countries of the world would be first opened out.

Although in most things he agreed thoroughly with Colonel Winterbotham, on the question of relative cost of aerial and ground surveying he did not quite agree. He (Prof. Jones) had not a tithe of Colonel Winterbotham's experience of surveying, but did not think it would be correct to say that the aerial surveying method was not economically feasible unless it could be done, say, for 8/- per square mile, because in saying that he was comparing the results obtained from an aerial survey with the results that would be obtained for £1 or 18/- per square mile by ground surveying. He was not quite clear what sort of map we should get from that kind of ground survey, but quite clearly it was not going to be one with much detail. By aerial methods we should have conventional maps made from aerial photographs, and we should also have the advantage of being able to consult the original photographs. If detailed information were required of a country that had been surveyed from the air, he imagined that one would look first at the map produced from the survey and then call for the photographs, and look for water holes, tree arrangements, and so on. He believed that such an amount of detailed information, which had never been available before, was going to be of enormous value in the breaking up of the new areas of the world that had not yet been developed.

Mr. GRIFFITH BREWER referred to some photographs exhibited at a meeting of the Society twenty years ago.* These were very clear pictures of the ground, taken at very small expense. They were taken from a small captive balloon, in which the camera was operated by an electric current. He had taken a large series of these pictures from his garden, sending up a small captive balloon of 500 cub. ft. capacity. It was kept in a small shed, was pulled out in the morning, run up to 1,500ft. on its cable, and it used to take photographs in any direction. It was then hauled down by means of an electric winch, and put back into its shed. He would send some of the pictures to the Secretary of the Society, because they would be interesting if added to the information given by Mr. Thomas. (Figs. 1

* *Vide* AERONAUTICAL JOURNAL, Vol. IX., 1905, p. 14.

to 6.) Such photographs could be obtained at less than £100 capital outlay, and they were quite satisfactory. In fact, he had found that he could take photographs in that way better than if he himself had been up.

Professor WATTS added a word of appreciation of Mr. Thomas's description of the application of aerial surveying to geology. Some of his photographs in this connection, and in connection with archæology, were of great beauty and interest, and he could suggest many other areas where he would like to see similar experimental work done. To geologists, perhaps, the fact that the method was useful to the botanist was to some extent a drawback, and he had noticed that the work, from the geological point of view, was of much more value in arid countries. The photographs of Palestine had brought out perfectly wonderfully the wind-etched character of the country. To the geologist, a new point of view such as this was under any circumstances of great importance. In surveying any country, the geologist had to see it from all possible aspects. He went underground if he could, he went all over it, saw it in all lights, in all directions, and at all times. The only direction from which he could not see it was above; this had now become feasible. Professor Heim, of Zurich, 35 or 40 years ago, had been occupied for many years in the north-east corner of Switzerland in constructing a wonderful model of that country. There is a copy of that model in the South Kensington Museum. It is the result of a life's work, and Professor Heim had told him that he had used no less than 700 photographs and sketches of details. He wished the model to be as exactly as possible a representation of the country, and, as one looked down on the model from a few feet above it, it was necessary to express it as the ground would be seen from a height of a quarter to half a mile above it. In those days, there being no other means of seeing it, Professor Heim went three times and drifted over the mountains in a balloon to see the colours of the rocks and vegetation from that distance. As a result, he had produced an absolutely accurate representation of the country. That showed, as well as it could be shown, the enormous value of this work for geological surveys, particularly in new countries and in countries difficult of access. Mr. Thomas had mentioned the use of his method of survey by oil men. In one field, at any rate, very important exploration work was being done. He sincerely hoped that the method might be cheapened and more widely applied, and anticipated that geology would greatly profit by it.

Mr. G. T. MCCAW, expressing thanks to Mr. Hamshaw Thomas for his interesting lecture and the photographs which he had shown, said he had given his hearers a knowledge of Palestine much in excess of what they had before. With regard to the late Major Griffiths, this, at least, might be said—he was one of the few who had gone in for development on the lines of the new conditions which arose after the war, and it was in that connection that his work shone most brilliantly. As Colonel Winterbotham had said, we should have to get rid of the war idea. Discussing the advantages of aerial surveys, as mentioned by Professor Melvill Jones, Mr. McCaw said he thought all were agreed that they had in some respects an immense advantage; but in official life, unfortunately, we were up against the finance question. If aeroplane surveys were going to cost £20 per square mile, we should simply have the Crown Colonies saying they could not afford it. He was not exaggerating when he mentioned the figure of £20 per square mile, because an estimate for a large area had recently been framed on that basis. We should have to get down, at any rate, to somewhere near the cost of ground detail survey before the Colonies would be in a position to say: "Go ahead with your aeroplane work." We should be only too glad to have the advantage of all those records which Prof. Melvill Jones had spoken of, because, as Mr. Hamshaw Thomas had said, they were permanent records which could be used always. They should be taken with the very best possible instruments, and in that connection he considered that we could leave things in the

hands of the Air Ministry, which is at present engaged in developing the best types of apparatus. We had not yet seen the most recent instruments produced in America. We had had the benefit, however, of a first-hand statement of progress there up to the beginning of last year. Some references to work in Canada and the United States will be found in Report (No. 1) of the Air Survey Committee, which for a considerable period has been advocating the design of machines adapted to the purpose of aerial survey.

The CHAIRMAN, speaking with regard to the cheapening of the aeroplane, pointed out that within the last year or two we had opened up a new field as regards the design of aeroplanes and the general view taken of it, and that was in the direction of cheap flying. He did not say that what had been done recently would enable an aircraft suitable for aerial survey work to be made, but we had got away from the idea that it was necessary to have enormous engines and a very costly aeroplane in order to fly; as soon as a definite specification was put before our designers, laying plenty of emphasis on the question of price and cost of running, he did not think it would be very long before a suitable aeroplane would be developed.

Mr. HAMSHAW THOMAS, replying to the discussion, expressed his thanks to the speakers for their kind references to his lecture. We really needed some terms to distinguish the various types of survey. He had not been talking about what most people in England regarded as surveying. He was rather talking about obtaining a record of a country, to show its salient features, their rough positions, and the resources and general character of that country, in such a way that it could be used for the development of that country and for various other purposes. He quite appreciated that this was different from what was often called a survey, but it was the type of work which occupied a large number of the surveyors in Canada and the Colonies. Of course, we needed to get accurate fixation points or features as much as we could, and he was very pleased to find that the Air Survey Committee was going so strong. It was rather a coincidence that on the same day that he delivered this lecture the first report of that Committee had been issued. He believed it would be followed by a long series of other reports, which would be of very great value. But we had to develop the thing from all points of view, and he wanted to bring forward in this paper not so much the methods, but what one could get out of aerial survey, because he did not think everyone realised what was its field, or that there were other sides of the question apart from making a topographical map. He considered that he would have done good if only he had brought before the notice of aeronautical people generally in England the need for a special survey type of aeroplane, and he was extremely interested to hear what General Brancker had said about the specifications he had brought home. He hoped they would be followed by the design of some new types. Dealing with Mr. Griffith Brewer's remarks, Mr. Thomas pointed out that balloon photography was almost out of the question in most cases because of the difficulty of getting a balloon to go where we wanted it to go. Balloon photography had a very limited application indeed for that reason. It was possible, of course, that in some circumstances it might be useful. The great point about the aeroplane was that it would go over places where the surveyor could not go on the ground, and would go where we wanted it to go. He hoped that, as a result of the lecture, further interest in the subject would be aroused, and that greater progress would be made in some of the numerous branches which the subject touched.

A hearty vote of thanks was accorded Mr. Thomas at the conclusion of the discussion.

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